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**Effects of Natural and Clearcut Disturbances on Small
Mammal and Bird Diversity in Conifer Dominated
Boreal Forests**

**Final Report
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- Disclaimer -

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**Effects of Fire and Harvest Disturbance on Small Mammal, Bird, and
Vegetation Diversity in Three Age-Classes of Conifer Dominated
Boreal Mixedwood Forest**

**A research project
prepared for**

Manning Diversified Forest Products Trust Fund

by

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October, 1999

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Executive Summary

There is widespread concern that current timber harvest strategies will alter the structure and the function of forest ecosystems resulting in a loss of plant and wildlife species. It has been suggested that timber harvest practices mimic a natural disturbance regime will maintain forest integrity, and thus biological diversity. With this approach to forest management in mind, this research project was set up to gather relevant research data on natural disturbance regimes. The specific objectives of this report were as follows:

1. to determine if harvest stands that follow current harvest guidelines will converge naturally with fire disturbed stands as time from disturbance increases.
2. to provide a list of guidelines supported by research that can be adopted in forest management based on a natural disturbance regime.

In this report, information was divided into two main sections: a comparison of vegetation structure between harvest and fire disturbed stands and a comparison of bird and small mammal diversity in harvest and fire disturbed stands. Each section has specific harvest guidelines based on approximating a naturally disturbed forest stand.

Incorporating these guidelines into harvest strategies may minimize the impact of harvesting on forest ecosystems. Research is needed to assess the effectiveness of these guidelines. The success of a natural disturbance approach to forest management hinges on gaining a full understanding of local fire regimes and on the degree to which forest managers will be able to implement the guidelines while balancing the many values that forest ecosystems provide to society, from aesthetics, to recreation, to wildlife.

1. Introduction

Due to ever increasing demands on the resources of the boreal forest, public and research interest has been piqued by the difficulties that arise in trying to maintain the integrity of the boreal ecosystem while allowing the many economic, social and recreational opportunities to continue. The idea has been put forth that timber harvest practices using a natural disturbance regime as a template for management strategies will maintain forest integrity, and with it, biological diversity (White and Pickett 1985, McComb *et.al.* 1993, Gauthier *et.al.* 1996).

Disturbance, such as fire, is a natural part of the boreal forest and plays an important role in determining ecosystem structure, composition and function (DesGranges and Rondeau 1992). Variation in disturbance size, intensity, and frequency creates a mosaic of habitats which supports a variety of wildlife (Telfer 1992). Before fire suppression, the boreal forest was dominated by a fire-disturbance regime to which each species is adapted (Wein 1991; Telfer 1992). Presently, large sectors of Alberta's boreal forest are subjected to large scale timber harvesting. Fire suppression and clearcut harvest practices are changing the type of disturbance dominating the landscape. The effect on wildlife and vegetation diversity is not known.

The natural disturbance approach to forest management is well supported by many theoretical papers (Franklin 1993; Hunter 1993; Galindo-Leal and Bunnell 1995), but largely remains an untested theory (but see Hickey 1994). Research is needed to first document the characteristics of fires so that management guidelines can be formulated and implemented. This information must be complemented by a test of the basic assumption of the natural disturbance approach to forest management. That is, forest management that conserves forest structure based on a natural disturbance model will maintain forest function, and thus, species diversity. This is a daunting task as the nature of fire disturbance is that it occurs on many different spatial and temporal scales. Therefore, it will require a number of studies at both the stand and landscape scale for researchers to begin to understand the complexities of a natural fire regime.

With the above considerations in mind, the present study examined the vegetation and structural characteristics of fire disturbance in three age-classes of white spruce dominated stands. These characteristics were compared to three age-classes of harvest disturbed stands. Instead of examining the variation of fire regimes, the variation found in fire disturbance was

controlled for by selecting burn stands of a specific age, a certain size and intensity, and with a particular pre-disturbance vegetation type. By holding these general variables constant, conclusions meaningful to forest management could be drawn about where the differences lie between harvest and fire disturbance at the stand scale. The purpose of this study was to document fire characteristics, determine if and how these characteristics differed from harvested stands, and determine if the integrity of the forest was conserved, or at least recovered, by comparing species diversity between these two disturbance types as time from disturbance increased.

This research will provide resource management agencies and the forest industry with the information needed to make sound management decisions on how to maintain structure and function at the stand scale through harvest site manipulation.

2. Experimental Design

This study was conducted in harvest and fire disturbed stands in three age-classes of white spruce dominated boreal forest. The study area (47 km²) was located in regions north and west of the town of Manning (58°, 117°), 92 km north of Peace River, Alberta, Canada (Figure 2.1).

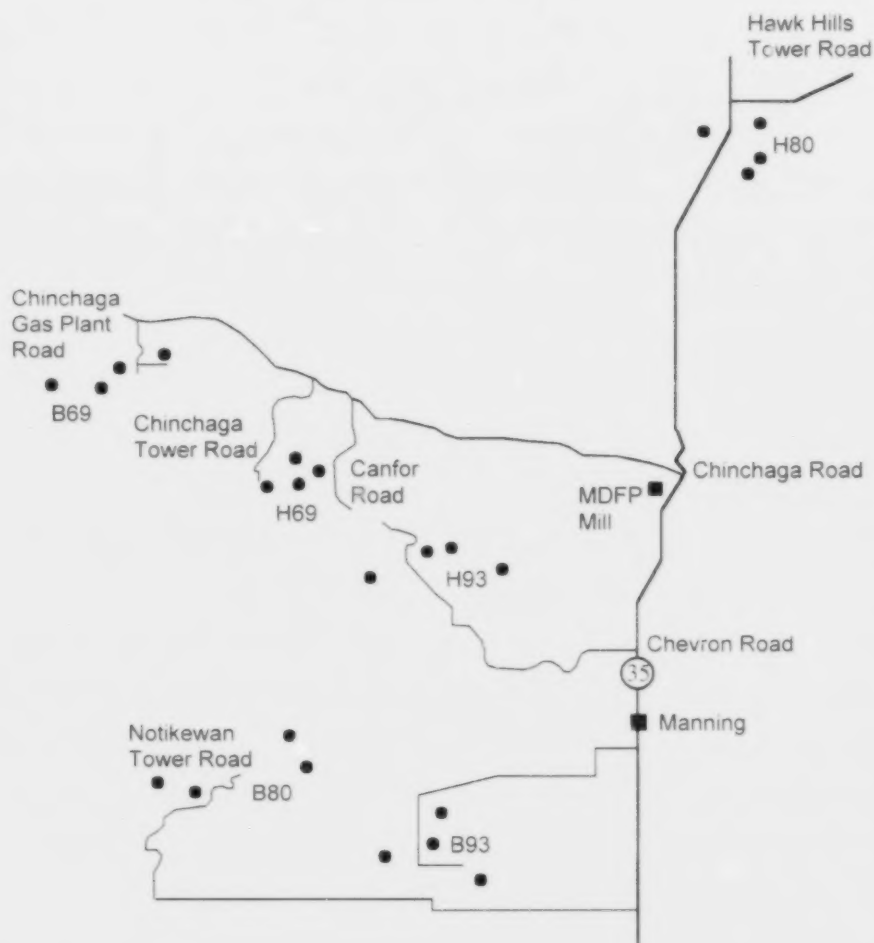


Figure 2.1. Schematic diagram of research stands in Alberta. H# or B# = harvest or burn stands, respectively, with the number indicating the origin year of disturbance.

Three age-classes of burn and harvest stands were selected with disturbance occurring in 1993, 1980, and 1969. The design consisted of a total of 24 stands with four burn and four harvest stands within each age-class. Three age-classes were chosen in order to determine if

convergence in vegetation and wildlife occurred between fire and harvest disturbed stands over time, but each age-class was selected for a specific reason. The three year age-class (3 years from the start of this study) was chosen to determine what occurred immediately after disturbance. The 16 year age-class was selected because at approximately this age, coniferous trees have reached a height of 3.0m. At this time, logging companies can harvest adjacent leaves in a two pass system (Alberta Environmental Protection 1994). The 27 year age-class was chosen for two reasons. Convergence between fire and harvest disturbed stands may have occurred by this age and it is the earliest date at which clearcut harvesting replaced selective logging in this area (logging records from Manning Forest Ranger Station).

Harvest strategies in this region target old stands, use a 110 year rotation age and use clearcut harvesting as the primary method of harvesting. Harvesting typically follows a two pass cutting regime resulting in an orthogonal patchwork of cut and uncut blocks (Alberta Environmental Protection 1994). The mean cutblock size harvested by Manning Diversified Forest Products (MDFP) in 1994/95 was 9.3ha and 17.4ha in 1995/96. Cutblocks are generally harvested in the winter and scarified and replanted in the summer months. For our sampling purposes, harvest stands between 14.7ha and 31.2ha situated on the edge of a cut/leave pattern were chosen. This layout represented realistic past and future harvesting practices, yet reduced the influence of nearby cutblocks. In order to be considered part of a cut/leave pattern, a cutblock had to be located within 1000m of another cutblock on one side, but have sufficient forested landscape between to allow for further harvesting. The remaining three sides of the cutblock had to be adjacent to a minimum of 1000m of undisturbed landscape. To ensure independence, sample stands were a minimum of 1000m apart.

Even before effective fire suppression was implemented in northern Alberta in the early 1980's, small fires largely dominated the fire disturbance regime in Alberta (Murphy 1985). In the Peace River Forest District, which encompasses the study area, 87% of all fires between 1960 and 1980 were less than 40.0ha in size (determined from fire records obtained from the Provincial Forest Fire Centre, Edmonton, Alberta). Small fire disturbances best represent the predominant fire regime in our study area and the one most effectively suppressed by fire control. Due to difficulties in accurately locating and accessing small fire disturbances, 15ha sites were selected in fingers of larger burns for each age-class. Fingers were defined as having three edges

adjacent to 1000m of undisturbed landscape. In order to further ensure that each stand was an independent sampling unit, each stand had to be a separate stand before the fire. With these considerations, burn stands located in larger fires most closely represented a small fire disturbance.

Although fires cross all vegetation boundaries (Sousa 1984), only fingers that were previously merchantable timber (large diameter white spruce-dominated, aspen/white spruce mix or white spruce/pine mix) were selected for study. Using stands with similar pre-disturbance vegetation to that of merchantable timber allowed for meaningful comparisons between fire and harvest disturbed stands, particularly for comparison of vegetation variables. As for harvest stands, burn stands had to be a minimum of 1000m apart to ensure independence.

Within each stand, a permanent 500m transect was positioned with no less than 125m distance between any point on the transect and the stand edge. It was relative to these permanent transects that all other points were located for vegetation, bird, and small mammal sampling.

3. Comparison of Vegetation Characteristics in Three Age-Classes of Burn and Harvest Sites in White Spruce Dominated Stands

3.1 Introduction

The natural disturbance approach to forest management focuses on conservation of forest structure with the assumption that conservation of function will follow. Indeed, Bunnell *et. al.* (1997) stated that..."the best way of conserving all species is to ensure that the system continues to have the same overall structure and function.". For example, live and dead trees (snags) provide nesting and foraging sites for birds and mammals (Gibbs *et. al.* 1993; McDonald 1995) and down woody material provides a substrate for various vascular and non-vascular plants (Crites 1995; Harmon *et. al.* 1989). However, there is virtually no information on structure following fire disturbance at the stand scale, particularly as it compares to harvested stands.

In terms of adopting the natural disturbance approach to forest management, there are two major areas of concern. First, management strategies must focus on retaining structural components at the harvest site to narrow the gap between harvest and natural disturbance. The very nature of timber harvesting is to remove the bulk of forest structure, whereas even the most intense fires leave most of the above ground biomass (Franklin 1993). Thus, the amount of residual structure that remains immediately following disturbance is likely where the greatest difference occurs between harvest and fire disturbance. The other area of concern, although not entirely separate, is regeneration and recovery of these structural components as time from disturbance increases. That is, how much can a harvested stand naturally recover from harvesting through regeneration and how much needs to be retained at the harvest site to ensure future convergence between fire and harvest disturbed sites.

Of all the many forest attributes, there are only a few that realistically can be manipulated by forest companies at the time of harvest or shortly thereafter. These include down woody material, snags, green tree retention, shrub density, and seedling density. This study focussed on these attributes and measured the characteristics immediately following disturbance that would be most useful to forest companies in maintaining these structures in a way that mimicked fire disturbance. However, as mentioned above, regeneration from time since disturbance, including decay, regrowth, and recolonization is also important to the natural disturbance approach to forest management. For this reason, these forest structures were measured in a chronosequence

of three age-classes and included a measure of shrub, saplings, poles, and vascular plant regeneration.

The purpose of this research was to provide information on structural characteristics following fire disturbance, and through time, to determine if fire differed from harvest disturbance and if any differences converged with time. These data were then used to develop a practical template for forest managers to employ the natural disturbance approach to forest management at the time of harvest.

3.2 Methods

3.2.1 Snag and Live Tree Sampling

In this study, snags and live trees were $\geq 10\text{cm}$ DBH, $\geq 2\text{m}$ in height, and had a vertical lean $< 45^\circ$. A plotless technique was used to sample snags and live trees (Clark and Evans 1954), thus allowing a measure of density and spatial distribution. Sample points were systematically located within each treatment stand. From this point, the distance to the nearest tree and snag was recorded in each of four quadrants. The distance between sampling points varied among treatment stands to accommodate differences in forest structure. The distance chosen was an estimate based on minimizing the occurrence of no snag or tree to sample, and thus, lowering the chance of overestimating density.

In 1993 burns, sampling points for live trees and snags were located at 40m intervals (each quadrat being 20m square), whereas 1993 harvest stands had sampling points located at 120m intervals. Sample points for the 1980 harvest stands were located at 80m intervals, but snag densities were so low in 1980 burns that snags were not sampled using this technique. This observation was confirmed by including sampling for large snags in the 5m $\times$ 5m quadrat technique (see Figure 3.2). No snags were found using this technique. However, live trees were sampled at 60m intervals. Sample points for both the 1969 burn and harvest stands were located at 80m intervals.

Each live tree and snag was identified to species and measured for diameter at breast height (DBH), height, and number of cavities. For snags, stage of decay was categorized using a classification system based on overall physical appearance (Figure 3.1).

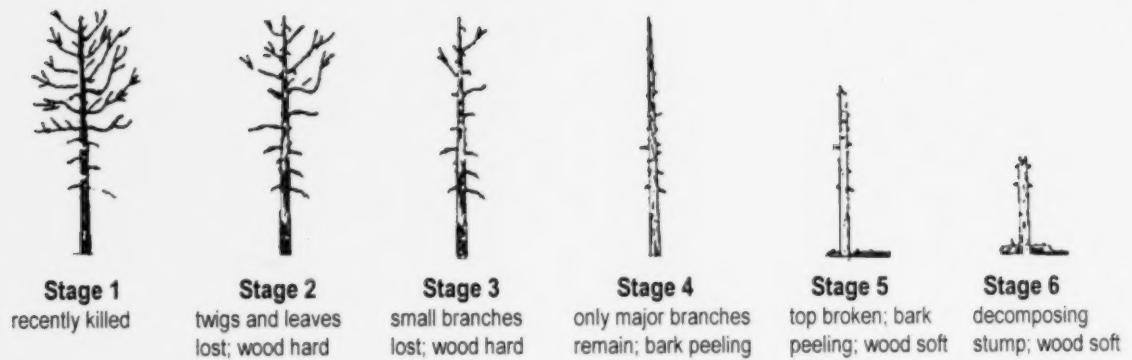


Figure 3.1. Schematic diagram of structural attributes used to classify stage of decay for snags.

3.2.2 Down Woody Material

In this study, down woody material (DWM) was divided into three groups; coarse DWM (logs ≥ 10 cm diameter and stumps ≥ 10 cm diameter and < 2 m in height), fine DWM (≤ 5 cm diameter), and medium DWM (> 5 and ≤ 10 cm diameter). A line intersect method was used to sample DWM (De Vries 1974). Within each stand, 12 sampling points were located 40m on either side of the permanent transect with 70m between each point along the permanent transect (Figure 3.2). At each sampling point, a 7m transect was extended at a direction of 90° along which coarse DWM was sampled.

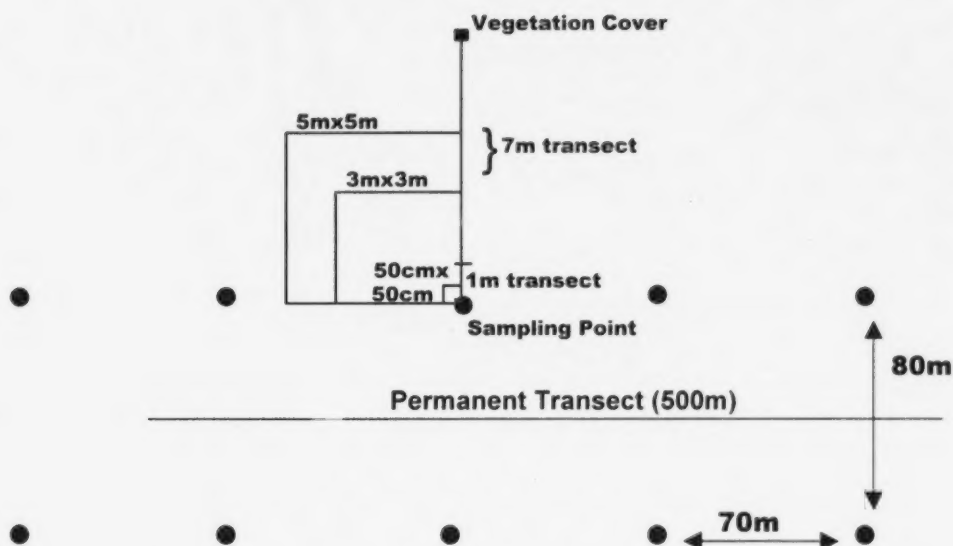


Figure 3.2. Design used to sample down woody material, low, medium and tall shrubs, sapling and seedling characteristics, small diameter trees and snags (<10cm DBH), duff depth, and vegetation cover. Twelve sampling points were located within each stand. Each sampling point was associated with a nested quadrat and a 7m transect.

Frequency of fine and medium DWM was recorded along the first metre of each 7m transect (Figure 3.2). A total of 12m were sampled per stand and 48m per treatment age. For coarse DWM and stumps, diameter, length (equivalent to height for stumps), and stage of decay were recorded for all wood that crossed the transect at any point along a 7m transect. A total of 84m were sampled per stand and 336m per treatment age. Stage of decay classification was based on physical attributes of the coarse DWM or stump (after Lee *et. al.* 1995; Table 3.1).

Table 3.1. Physical attributes used to classify stage of decay for stumps and coarse down woody material.

Decay Stage	Physical Characteristics
1	log whole and undecayed; bark, branches, and twigs intact; log elevated on support points; wood hard
2	log sound and wood hard; twigs mostly lacking; <50% bark missing
3	some branches remaining; >50% bark missing; wood soft in places
4	little or no bark remaining; no branches; wood fungi present; wood soft with small crevices and pieces lost
5	large wood fragments lost; outline of trunk deformed; vascular plants beginning to colonize
6	wood mostly well decayed; log completely moss covered and colonized by various vascular plants
7	humification nearly 100%; difficult to define as log; outline indeterminable; no evidence of hard wood

3.2.3 Understory Communities

Nested quadrats were used to sample the low (<1m in height), medium ($\geq$ 1m in height), and tall ($\geq$ 3m in height) understory characteristics. In each stand, twelve nested quadrats were located 40m on either side of the permanent transect with 70m between sampling points (Figure 3.2). Number and species were recorded for live and dead poles (<10cm DBH and $\geq$ 3m in height) in a 5mx5m quadrat. A 3mx3m quadrat was used to sample species and number of seedlings (live trees <1m in height and <10cm DBH), saplings ($\geq$ 1m height to <3m in height; <10cm DBH), and shrubs ($\geq$ 1m in height). A visual estimate of percent cover for small shrubs (<1m in height), herbs, grasses, moss, soil rock, water, wood, and litter was obtained for a 50cmx50cm quadrat. Occurrence of species was recorded for low shrubs and herbs in this quadrat. Twelve of each quadrat size were sampled per stand for a total of 48 quadrats per treatment age.

3.2.4 Duff Layer

Depth of duff layer was measured at 1m intervals along the 7m transect used to sample coarse DWM (Figure 3.2). There were seven measurements per transect for a total of 84

measurements per stand and a total of 336 measurements per treatment age. Measurements were obtained by inserting a ruler into the duff layer until solid ground was reached.

3.2.5 Vegetation Cover

Sampling points for vegetation cover were located at the end of each of the twelve 7m transects used to sample DWM (Figure 3.2). Two estimates of vegetation cover were obtained for each sampling point; at approximately 15cm above ground and 1.5m above ground. Estimates of vegetation cover were made by looking up through a circular tube (3.6cm in length x 3.7cm in diameter) and estimating the amount of sky blocked by vegetation. Twelve samples at each height were sampled per stand for a total of 48 samples per treatment age.

3.2.6 Data Analysis

Densities of trees and snags for each stand were calculated using the nearest neighbor distance (Clark and Evans 1954):

$$m = \frac{l}{4 \bar{r}^2}$$

where m = density per unit area, and $\bar{r}$ = mean distance to sample point.

To compare density of large diameter trees and snags at the stand level, nested analysis of variance was used. Density values were calculated at the stand level and each of the four stands were nested within their respective treatment types; burn or harvest. Spatial distribution of large diameter trees and snags was compared using variance component analysis. This analysis tested whether density of trees and snags calculated at the site level had the same spatial distribution within and among stands for each treatment within each age-class.

The same analysis used above was applied to volume and density of coarse DWM. The formula to calculate volume was as follows (DeVries 1974):

$$V = \left\{ \frac{\pi^2}{8L} \right\} \sum_{i=1} (d_i)^2$$

where V = mean volume per unit area, L = length of sample line, and d_i = diameter of log intersecting the sample line. Density of coarse DWM was derived using the following formula (DeVries 1974):

$$\hat{\chi} = (\pi/2L) \sum_n (1/l_i)$$

where $\hat{\chi}$ = mean density per unit area, l_i = length of i th log, L = length of sample line, and n = number of logs intersecting the line.

Characteristics of large diameter trees, snags, and down woody material such as diameter, pattern of decay and species composition, as well as frequency and species composition for the remaining vegetation variables were compared using blocked analysis of variance (Zar 1996). Individual stands ($n=4$) were nested within burn and harvest treatment types for the among-subjects factor. The categories for respective characteristics were used as the within-subjects factor. Effect of treatment on total abundance of a vegetation variable were determined using the main effect term between subjects. Effect of treatment on relative abundance among categories was determined using the within subjects interaction term. To interpret these data, a significance level of 0.10 was used as it has been suggested that Type II errors in applied research can be more costly than Type I errors (Schmiegelow *et. al.* 1997). To determine where differences among categories occurred, either an Independent T-test or a Mann Whitney test with tied ranks was used.

3.3 Results

3.3.1 Large Diameter Trees (≥ 10 cm DBH)

In the 1993 age-class, a total of ten trees were sampled in four burn stands and 90 trees in four harvest stands. A total of 12 trees were sampled in the 1980 burn stands as compared to 148 trees in the 1980 harvest stands. In the 1969 age-class, 138 trees were sampled in the burn treatments and 144 trees in the harvest treatments.

Tree Density

In the 1993 age-class, tree densities were relatively low in both treatment types, but densities were three times higher in harvest stands (1.8 ± 0.5 trees/ha; mean $\pm$ S.E.) than burn

stands (0.6 ± 0.6 trees/ha). Because the number of live trees sampled was so low in the 1993 burn stands, using analysis of variance would overestimate the density of trees in burn stands. For both the 1993 and 1980 age-classes, the calculated density of live trees at the stand level was compared using an independent t-test. The difference in tree densities was not significant ($t_{0.01(1),3,3}=1.761$, $p=0.129$; Figure 3.3).

In the 1980 age-class, tree densities increased in both treatment types, but the increase in harvest stands was much greater resulting in a significant difference in tree densities between burn (1.1 ± 0.4 trees/ha) and harvest stands (18.4 ± 4.2 trees/ha; $t_{0.01(1),3,3}=4.074$, $p=0.007$; Figure 3.3).

The trend continued in the 1969 age-class for tree densities to increase. Although average density was more than twice as great in harvest stands (64.4 ± 19.6 trees/ha) than burn stands (23.0 ± 12.9 trees/ha), large variation among treatment stands rendered the difference insignificant (nested ANOVA; $F=0.570$, $df=1$, $p=0.451$; Figure 3.3).

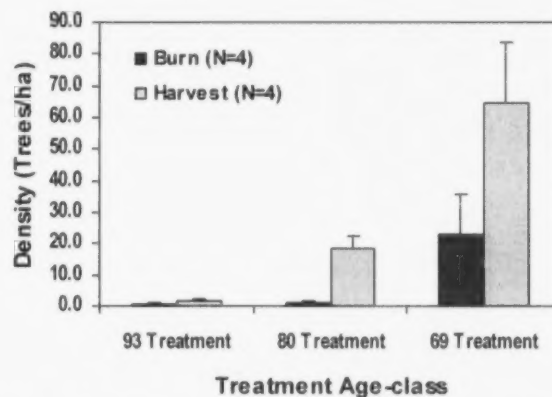


Figure 3.3. Densities of large diameter trees (≥ 10 cm DBH) for burn ($N=4$) and harvest ($N=4$) stands in 1993, 1980, and 1969 disturbance age-classes in white spruce-dominated stands in Alberta.

Spatial Pattern of Trees

Because so few large diameter trees were found in the 1993 and 1980 age-classes for the burn stands, it was not feasible to statistically compare the spatial distribution of trees among and within stands without a large bias towards spatial homogeneity for these treatments. Visual examination of the data showed that in the 1993 burn stands, all ten live trees were found in one stand and spread over seven of the 28 sampling points. In the 1980

burn stands, seven trees were found in one stand and five trees in another stand. In both stands, the trees were clustered in two of the 18 sampling points.

For the remaining stands, the spatial pattern of trees was homogenous among stands within each treatment age-class with the exception of the 1980 harvest stands (Table 3.2).

Tree density was homogenous within stands for all treatment age-classes.

Table 3.2. Variance component analysis on tree (≥ 10 cm DBH) densities within and among stands for harvest stands in the 1993 and 1980 age-classes and burn and harvest stands in the 1969 age-class.

Variance	Source	df	MS	F	P
93 Harvest	Stand	3	262949.15	1.596	0.235
	Site	7	112353.16	0.682	0.686
	Error	14	164756.80		
80 Harvest	Stand	3	51897.87	2.663	0.072
	Site	9	10512.90	0.542	0.828
	Error	23	19491.35		
69 Burn	Stand	3	6801991.90	1.427	0.260
	Site	9	4000165.60	0.839	0.588
	Error	23	4765541.90		
69 Harvest	Stand	3	5883775.40	1.025	0.400
	Site	9	3648468.20	0.635	0.758
	Error	23	5741346.30		

Size Distribution of Trees

In the 1993 and 1980 age-classes, only a comparison at the stand level of average tree diameters was possible given the small number of trees sampled and their tendency to be clumped in one stand. In the 1993 age-class, average tree diameter was greater in harvest stands (21.4 ± 2.8 cm; mean $\pm$ S.E.) than burn stands (16.0 ± 0.0 cm), but the difference was not significant (independent t-test; $t_{0.01(1),0.3} = 0.846$, $p = 3.460$; Figure 3.4a). Divergence occurred in the 1980 age-class with average tree diameter in the 1980 burn stands (29.6 ± 9.6 cm) twice as great as average tree diameter in the 1980 harvest stands (14.4 ± 1.4 cm; $t_{0.01(1),1.3} = 2.428$, $p = 0.072$; Figure 3.4b).

In the 1969 age-class, average tree diameter was lower in burn stands (12.7 ± 0.3 cm) than harvest stands (16.8 ± 2.1 cm; nested ANOVA; $F = 44.37$, $df = 1$, $p < 0.000$; Figure 3.4c).

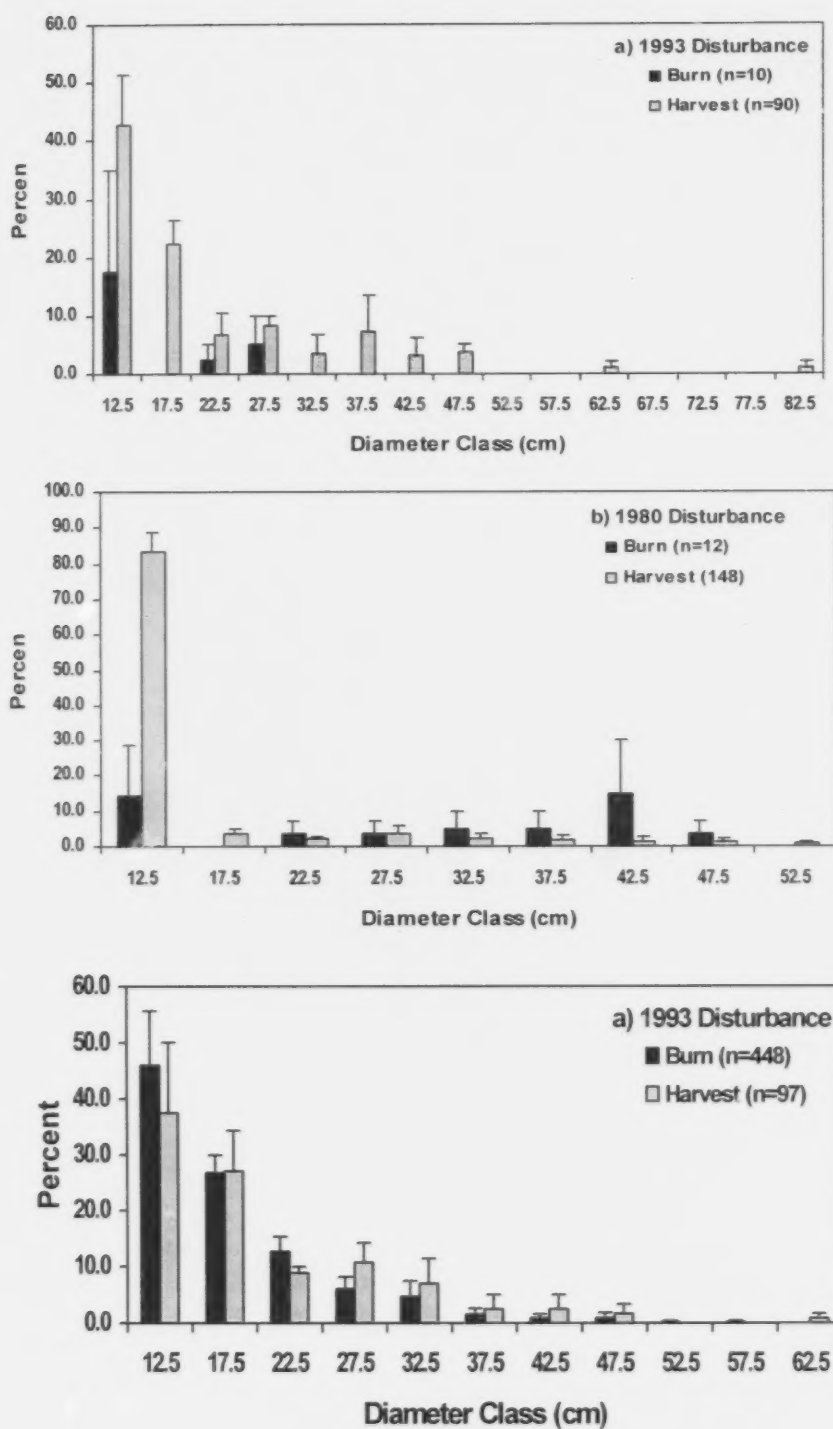


Figure 3.4. Distribution of trees (≥10cm DBH) in diameter classes for burn (N=4) and harvest (N=4) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes of white spruce-dominated stands.

Density of Cavities in Large Diameter Trees

Only three cavities were found in 542 live trees sampled across all treatment age-classes. Two cavities were found in one of the 1980 harvest stands and one was found in a 1969 harvest stand giving an average cavity density of 0.02 cavities/ha and 0.008 cavities/ha for the respective treatment types.

Species Composition of Trees

In the 1993 and 1980 age-class, species composition differed between the two treatment types (blocked ANOVA; $F=4.960$, $df=6$, $p=0.001$ and $F=3.453$, $df=6$, $p=0.008$, respectively; Figure 3.5a and b). However, it should be noted that these results were confounded by the lack of tree species data in the 1993 and 1980 burn stands. In the 1969 age-class, no difference in species composition was found between burn and harvest stands ($F=1.837$, $df=6$, $p=0.119$; Figure 3.5c).

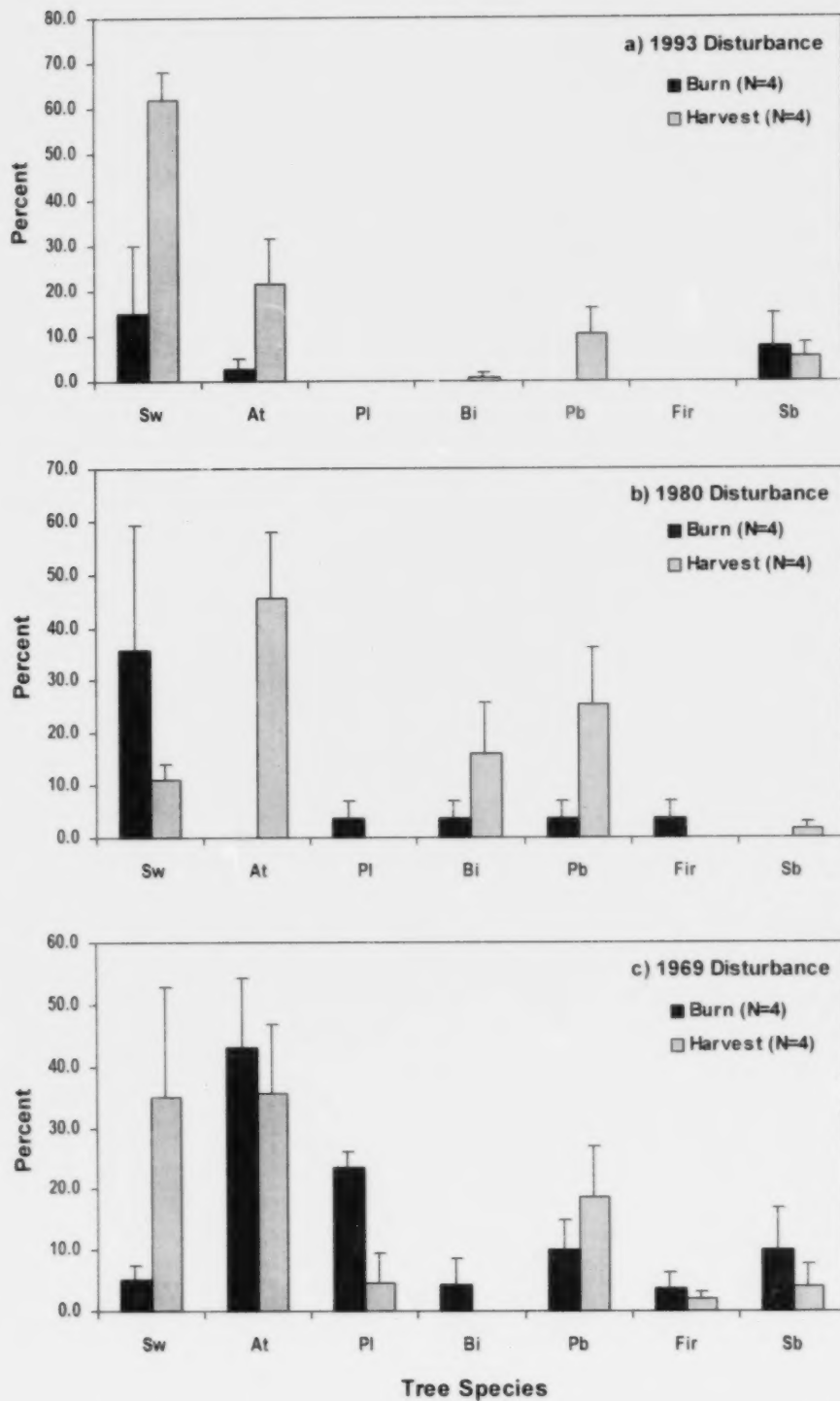


Figure 3.5. Distribution of tree species in burn and harvest treatments for a) 1993, b) 1980, and c) 1969 disturbance age-classes of white spruce-dominated stands. SW=white spruce, Pl=lodgepole pine, At=trembling aspen, Bi=paper birch, Pb=balsam poplar, Fir=balsam fir, and Sb=black spruce.

3.3.2 Large Diameter Snags ($\geq 10\text{cm DBH}$)

In the 1993 age-class, a total of 448 snags were sampled in four burn stands and 97 snags in four harvest stands. A total of 288 snags were sampled in the 1980 burn stands as compared to 110 snags in the 1980 harvest stands. In the 1969 age-class, 144 snags were sampled in the burn treatments and 137 snags in the harvest treatments.

Snag Density

Snag density was more than 100 times greater in 1993 burn versus harvest stands (nested ANOVA; $F=42.455$, $df=1$, $p=0.001$; Figure 3.6). Although snag density decreased with time since disturbance in burn stands and slightly increased in harvest stands, snag density was almost 12 times greater in burn stands (49.5 ± 15.9 snags/ha) compared to harvest stands (4.2 ± 2.1 snags/ha) in the 1980 age-class ($F=8.029$, $df=1$, $p=0.030$). As snag density continued to decrease with time since disturbance in burn stands (15.6 ± 9.1 snags/ha), the difference in density compared to harvest stands (4.3 ± 0.5 snags/ha) was no longer significant in the 1969 age-class ($F=1.531$, $df=1$, $p=0.262$).

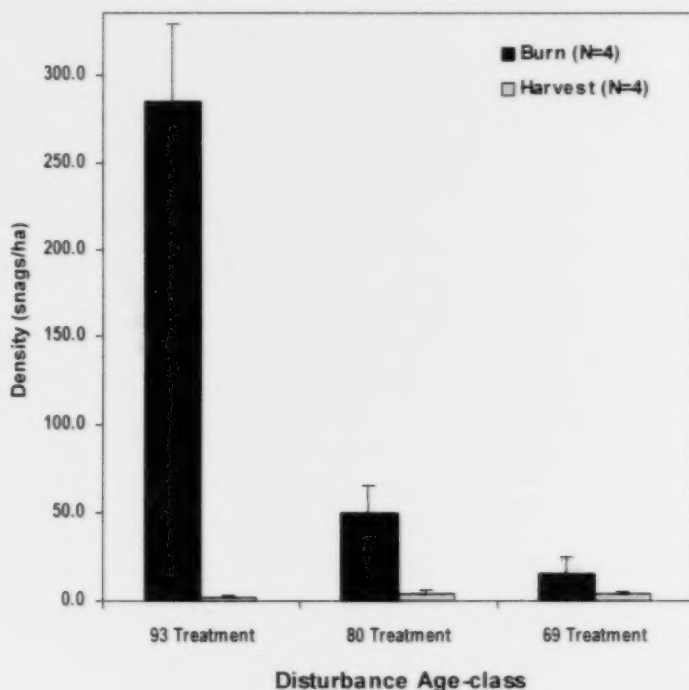


Figure 3.6. Density of large diameter snags ($\geq 10\text{cm DBH}$) in burn ($N=4$) and harvest ($N=4$) treatments in three disturbance age-classes of white spruce-dominated forest.

Spatial Pattern of Snags

Spatial pattern of snags was homogenous within stands for burn and harvest treatments in each age-class (Table 3.3). Spatial heterogeneity of snags existed among stands for the 1980 harvest and 1969 burn stands. It appeared that the spatial pattern of snags among stands diverged with time since disturbance for burn treatments, but no obvious pattern existed for harvest treatments.

Table 3.3. Variance component analysis on snag (≥ 10 cm DBH) densities within and among stands for burn and harvest stands within each age class.

Variance	Source	df	MS	F	P
93 Burn	Stand	3	245957.32	0.541	0.655
	Site	27	495237.39	1.040	0.372
	Error	81	454293.76		
93 Harvest	Stand	3	88.14	0.703	0.567
	Site	7	157.89	1.259	0.341
	Error	13	125.42		
80 Burn	Stand	3	47335.59	2.702	0.055
	Site	17	12704.60	0.725	0.763
	Error	51	17519.74		
80 Harvest	Stand	3	409.43	13.456	<0.000
	Site	9	27.05	0.889	0.549
	Error	24	30.43		
69 Burn	Stand	3	10408.32	5.884	0.004
	Site	19	1709.94	0.967	0.491
	Error	23	1769.74		
69 Harvest	Stand	3	604.02	1.393	0.270
	Site	9	264.38	0.610	0.776
	Error	23	433.69		

Size Distribution of Snags

The average diameter for snags in 1993 burn stands (17.9 ± 0.4 cm) was less than that in 1993 harvest stands (20.8 ± 1.0 cm; nested ANOVA; $F=13.63$, $df=1$, $p<0.000$) with a range of 10.0-56.0cm DBH for burn stands and 10.1-63.1cm DBH for harvest stands (Figure 3.7a). The size distribution of snags did not differ significantly between the two treatment types (blocked ANOVA; $F=0.313$, $df=10$, $p=0.975$).

Average snag diameter increased in the 1980 age-class for both burn (22.4 ± 0.6 cm) and harvest (29.2 ± 1.1 cm) treatments, but the increase was greater for harvest treatments resulting

in a significant difference between average snag diameters ($F=40.47$, $df=1$, $p<0.000$). The range in snag diameter was 10.1-68.1cm DBH in burn stands and 10.7-64.0cm DBH in harvest stands. The distribution of snags among diameter categories differed between treatment types ($F=2.311$, $df=11$, $p=0.018$; Figure 3.7b) with percentage of snags in the 20.0-24.9cm DBH size-class three times greater in burns than harvest stands ($t_{0.10,(2),3,3}=3.452$, $p=0.014$) and percentage of snags in the 30.0-34.9cm DBH size-class greater in harvest stands than burn stands ($t_{0.10,(2),3,3}=2.231$, $p=0.066$).

In the 1969 age-class, average snag diameters decreased to 19.7 ± 0.7 cm in the burn treatment and 25.6 ± 0.8 cm in the harvest treatment, but the difference in average snag diameter remained significant ($F=33.32$, $df=11$, $p<0.000$). The range in snag diameter was 10.0-46.7cm DBH in burn stands and 10.7-60.7cm DBH in harvest stands. Once again, the size distribution differed between treatment types ($F=2.069$, $df=10$, $p=0.041$; Figure 3.7c) with 2.5 times greater percentage of snags in the 10.0-14.9cm DBH size-class in burn stands ($t_{0.10,(2),3,3}=2.132$, $p=0.077$) and five times greater percentage of snags in the 40.0-44.9cm DBH size category in harvest stands ($t_{0.10,(2),3,3}=2.018$, $p=0.051$).

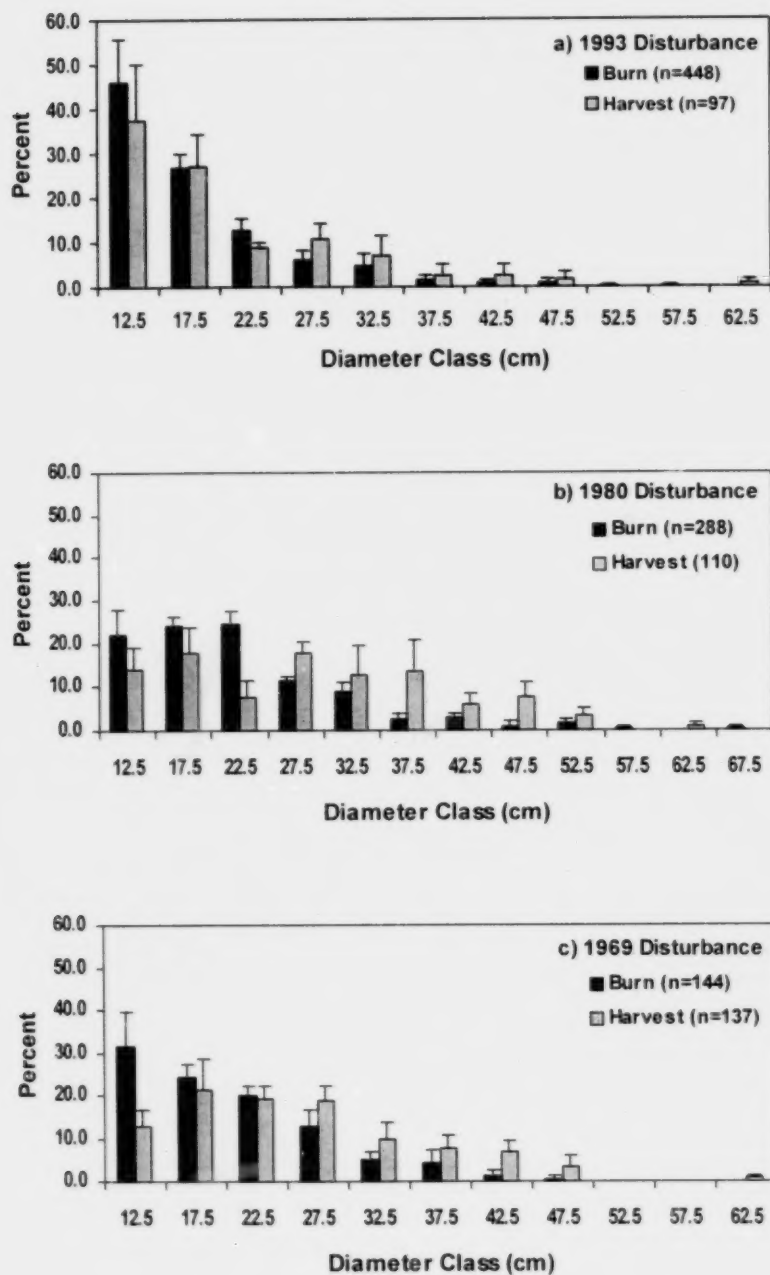


Figure 3.7. Percentage of snags (≥10cm DBH) in diameter size classes for burn (N=4) and harvest (N=4) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes in white spruce-dominated stands.

Cavity Density

The density of cavities in snags in the 1993 age-class was significantly greater in burn treatments (2.7 cavities/ha) as no cavities were found in harvest treatments (nested ANOVA; $F=8.106$, $df=1$, $p=0.029$; Figure 3.8). Cavity density decreased in burn treatments and increased in harvest treatments with time since disturbance so that no difference in cavity density existed between burn and harvest treatments in either the 1980 and 1969 age-classes ($F=0.012$, $df=1$, $p=0.917$ and $F=0.001$, $df=1$, $p=0.974$).

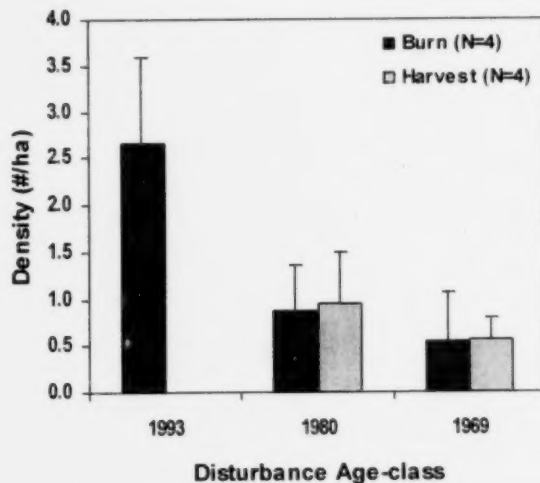


Figure 3.8. Average density of cavities in snags (≥ 10 cm DBH) for burn (N=4) and harvest (N=4) treatments in 1993, 1980, and 1969 disturbance age-classes in white spruce-dominated stands.

Pattern of Decay

The decay pattern for snags in the 1993 age-class differed between treatment types (blocked ANOVA; $F=12.130$, $df=5$, $p<0.000$; Figure 3.9a). The 1993 burn snags exhibited a distinct curve piquing at decay stage 3 (58%; Mann-Whitney test; $U_{0.10,(2),4,4}=0.020$) and with a greater percentage of snags occurring in stage 4 ($U_{0.10,(2),3,3}=0.081$). The harvest treatment had more snags in decay stages 5 (33%; $U_{0.10,(2),4,4}=0.020$) and 6 (13%; $U_{0.10,(2),4,4}=0.043$).

As compared to the 1993 age-class, percentage of snags found in the higher decay stages was greater for both 1980 burn and harvest treatments, although the shift to higher stages of decay was greater in the 1980 harvest stands (Figure 3.9b). Thus, the separation in decay pattern remained distinct between treatment types as most snags were found in decay stage 3 in burn stands (38%) and in stage 5 in harvest stands (60%; $F=15.618$, $df=4$,

$p < 0.000$). Other than stage 1 of decay where no snags were found in burns or harvests, the difference in the percentage of snags between treatment types for the remaining stages of decay were significantly different ($U_{0.10,(2),4,4}=0.080$, $U_{0.10,(2),4,4}=0.019$, $U_{0.10,(2),4,4}=0.021$, $U_{0.10,(2),4,4}=0.021$, $U_{0.10,(2),4,4}=0.043$).

The pattern of decay between burn and harvest stands in the 1969 age-class appeared to converge somewhat as snags in both treatment types entered the higher decay stages (Figure 3.9c). However, the difference between the two disturbance types remained significant with decay pattern skewed towards the higher decay stages in harvest stands as compared to burn stands ($F=7.050$, $df=5$, $p < 0.000$). The majority of snags were in decay stages 3 (26%; $U_{0.10,(2),4,4}=0.021$) and 4 (37%; $U_{0.10,(2),4,4}=0.083$) in burn treatments and in stages 5 (40%; $U_{0.10,(2),4,4}=0.080$) and 6 (26%; $U_{0.10,(2),4,4}=0.019$) in harvest treatments.

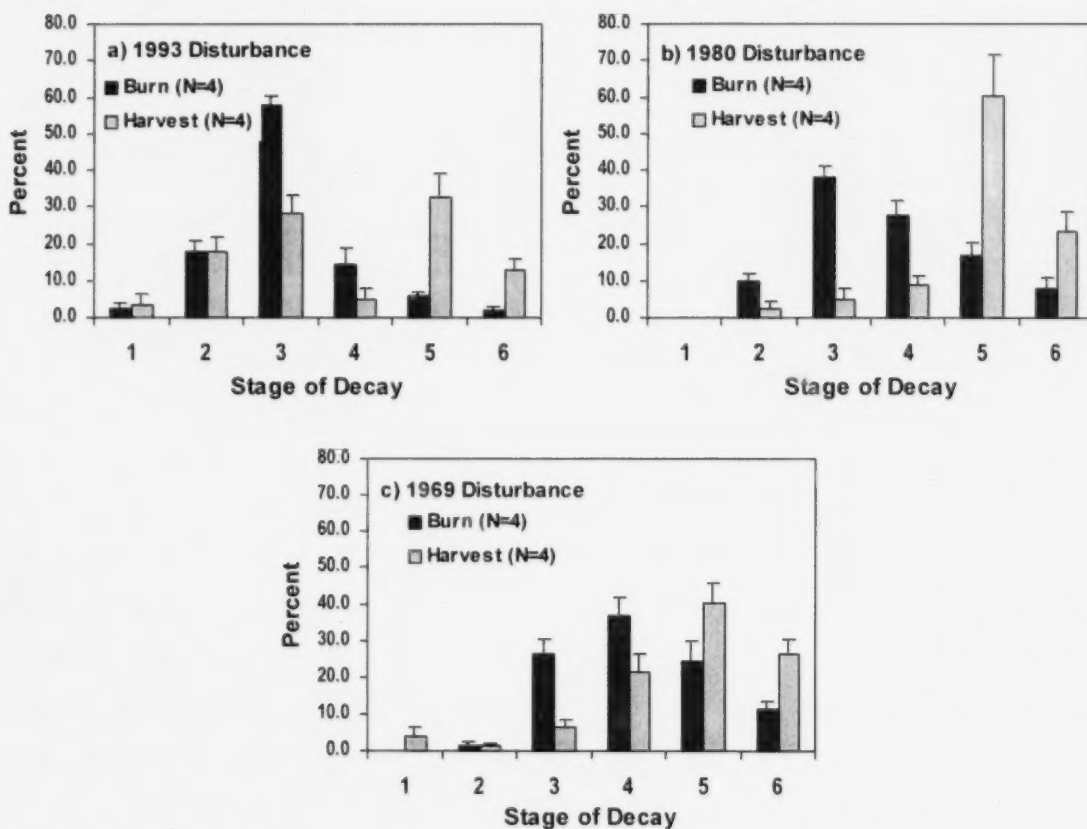


Figure 3.9. Stage of decay for snags in burn and harvest treatments in three disturbance age-classes a) 1993, b) 1980, and c) 1969 of white spruce-dominated stands.

Species Composition of Snags

Species distribution was similar between the two treatment types (blocked ANOVA; $F=0.731$, $df=7$, $p=0.647$) in the 1993 age-class, but pine snags (4.2%) were found exclusively in burn stands and birch (3.7%), fir (0.9%) and alder (1.0%) snags occurred only in harvest stands (Figure 3.10a).

In the 1980 age-class, species distribution was different between burn and harvest stands ($F=3.015$, $df=6$, $p=0.017$). Spruce (75.3%; $U_{0.10,(2),4,4}=0.083$) and pine snags (8.0%; $U_{0.10,(2),4,4}=0.047$) were found more often in burn stands, whereas balsam poplar snags (19.5%; $U_{0.10,(2),4,4}=0.091$) were more common in harvest stands (Figure 3.10b).

Species distribution also differed between treatment types in the 1969 age-class ($F=2.8998$, $df=6$, $p=0.021$). Aspen snags (9.6%; $U_{0.10,(2),4,4}=0.083$) and balsam poplar snags ($U_{0.10,(2),4,4}=0.091$) were more common in harvest stands than burn stands (Figure 3.10c).

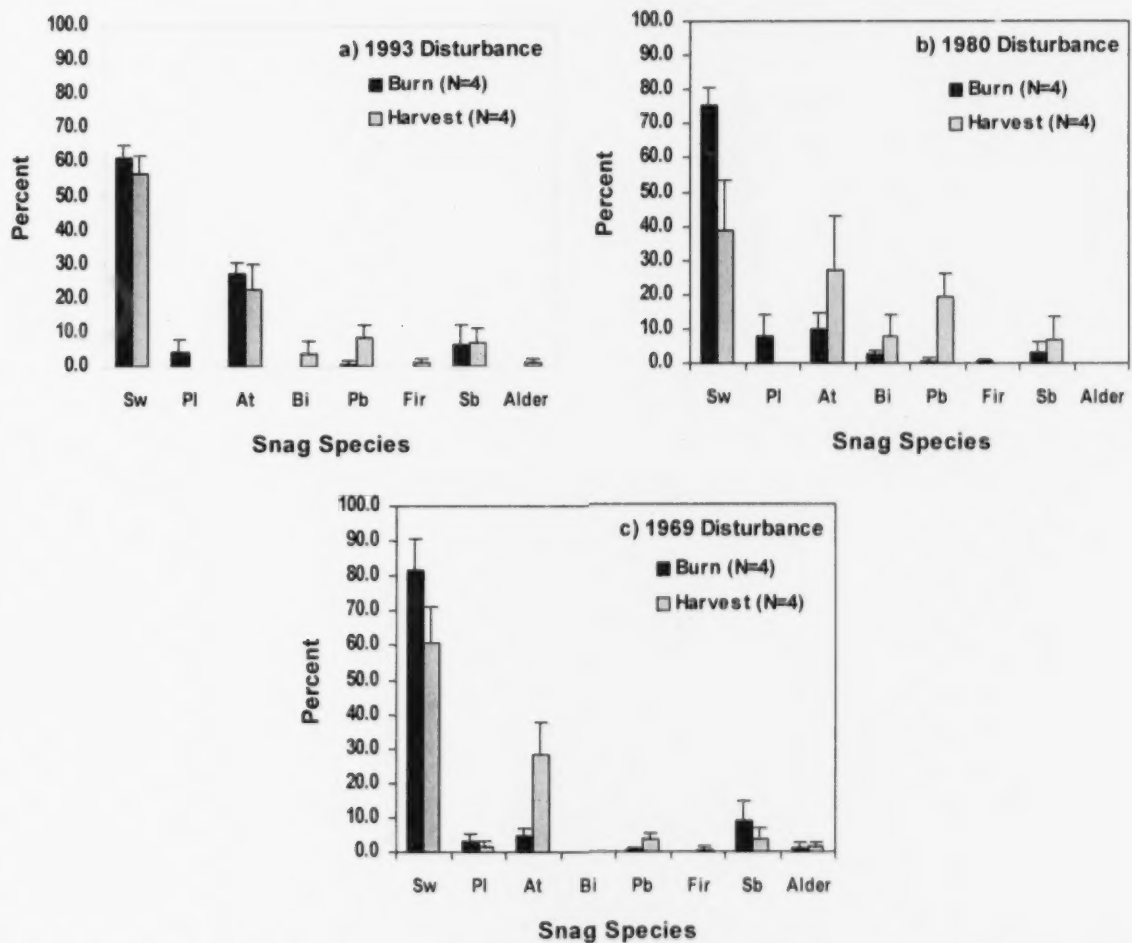


Figure 3.10. Distribution of snag species in burn and harvest treatments for a) 1993, b) 1980, and c) 1969 disturbance age-classes of white spruce dominated stands. Sw=white spruce, Pl=lodgepole pine, At= trembling aspen, Bi=paper birch, Pb=balsam poplar, Fir=balsam fir, Sb=black spruce.

3.3.3 Coarse Down Woody Material

Volume and Density of Coarse Down Woody Material

In the 1993 age-class, 45 pieces of coarse DWM were sampled in the burn treatment as compared to 115 pieces in the harvest treatments. In the 1980 and 1969 age-classes, the incidence of coarse DWM in burn stands was 218 and 248, respectively, and 125 and 147, respectively, in harvest stands.

Volume of coarse DWM in the 1993 age-class was six times greater in harvest stands ($18.0 \pm 4.5 \text{ m}^3/\text{ha}$) than burn stands ($3.0 \pm 0.3 \text{ m}^3/\text{ha}$; nested ANOVA; $F=11.159$, $df=1$, $p=0.016$; Figure 3.11). Volume of coarse DWM increased in the 1980 and 1969 age-classes

for burn treatments ($22.2 \pm 4.6 \text{ m}^3/\text{ha}$ and $24.3 \pm 2.5 \text{ m}^3/\text{ha}$) to levels equivalent to the 1980 and 1969 harvest stands ($22.0 \pm 5.1 \text{ m}^3/\text{ha}$ and $23.6 \pm 2.9 \text{ m}^3/\text{ha}$; $F=0.001$, $df=1$, $p=0.979$ and $F=0.035$, $df=1$, $p=0.858$, respectively).

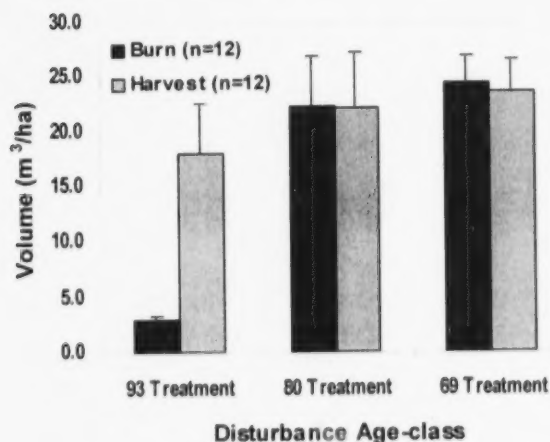


Figure 3.11. Volume of coarse down woody material in burn ($N=4$) and harvest ($N=4$) stands in three disturbance age-classes of white-spruce dominated forests. Volume was based on number and diameter of coarse down woody material crossing a transect. In the case of harvest stands, harvested stumps were included in the calculations.

Similar to patterns seen with volume, density of coarse DWM was 16 times greater in 1993 harvest stands as compared to 1993 burn stands (0.54 ± 0.1 pieces/7m and 0.04 ± 0.005 pieces/7m; $F=13.860$, $df=1$, $p=0.010$; Figure 3.12). The difference between treatment types decreased with time since disturbance as coarse DWM density steadily increased in burn stands (0.1 ± 0.03 pieces/7m and 0.2 ± 0.05 pieces/7m) while leveling off in harvest stands (0.4 ± 0.2 pieces/7m and 0.4 ± 0.2 pieces/7m; 1980 disturbance $F=2.232$, $df=1$, $p=0.186$ and 1969 disturbance $F=2.695$, $df=1$, $p=0.155$).

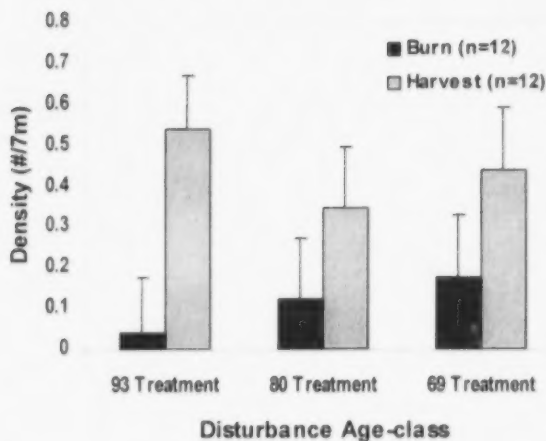


Figure 3.12. Density of coarse down woody material in burn (N=4) and harvest (N=4) stands in three disturbance age-classes of white-spruce dominated stands. Density was based on the number and length of coarse down woody material intersecting a transect (see Methods). For harvest stands, stumps were included in the calculations.

Spatial Distribution of Coarse DWM

In the 1993 age-class, spatial pattern of coarse DWM volume was homogenous among stands for burns, but not for harvest stands (Table 3.4). The opposite occurred at the site level where spatial homogeneity was exhibited within harvest stands, but not within burn stands.

In the 1980 age-class, spatial pattern of coarse DWM was similar between treatments at both the site and stand level. Coarse DWM was homogenous among stands and heterogeneous within stands.

The spatial pattern was also similar between treatments in the 1969 age-class, but in this case, the spatial patterns were homogenous both within and among stands.

Table 3.4. Variance component analysis on coarse DWM (≥ 10 cm diameter) volumes within and among stands for burn and harvest stands within each age-class.

Variance	Source	df	MS	F	P
93 Burn	Stand	3	200.72	0.134	0.939
	Site	11	3332.65	2.225	0.038
	Error	33	1498.13		
93 Harvest	Stand	3	111861.66	2.287	0.097
	Site	11	60900.58	1.245	0.298
	Error	33	48910.64		
80 Burn	Stand	3	78837.98	2.710	0.061
	Site	11	31543.01	1.084	0.403
	Error	33	29088.81		
80 Harvest	Stand	3	88902.91	2.772	0.057
	Site	11	50263.88	1.567	0.155
	Error	33	32069.77		
69 Burn	Stand	3	20836.61	1.136	0.349
	Site	11	15845.41	0.864	0.582
	Error	33	18348.86		
69 Harvest	Stand	3	29756.44	0.834	0.485
	Site	11	19123.32	0.536	0.864
	Error	33	35659.41		

Size Distribution

The average diameter of coarse DWM in 1993 burn stands (14.4 ± 0.7 cm) was lower than that found in 1993 harvest stands (20.3 ± 1.2 cm; nested ANOVA; $F=8.78$, $df=1$, $p=0.004$). However, the percentage of coarse DWM in each diameter class was very similar between the two treatment types (blocked ANOVA; $F=1.508$, $df=10$, $p=0.159$; Figure 3.13a).

As with the 1993 age-class, average diameter of coarse DWM in the 1980 age-class was lower in burn stands (17.2 ± 0.5 cm) than harvest stands (22.2 ± 1.0 cm; $F=28.11$, $df=1$, $p<0.000$). However, the distribution pattern between the two treatment types differed ($F=1.850$, $df=13$, $p=0.050$; Figure 3.13b) with greater percentages of coarse DWM in the 25.0-29.9cm category (Mann-Whitney Test; $U_{0.10(2),4,4}=0.091$).

As with the other age-classes, the difference in diameter of coarse DWM in the 1969 age-class was significant ($F=18.74$, $df=1$, $p<0.000$) with a greater average diameter in the

harvest stands (20.8 ± 0.9 cm) than the burn stands (17.2 ± 0.4 cm). The distribution pattern between treatment types was very similar ($F=0.681$, $df=13$, $p=0.776$; Figure 3.13c).

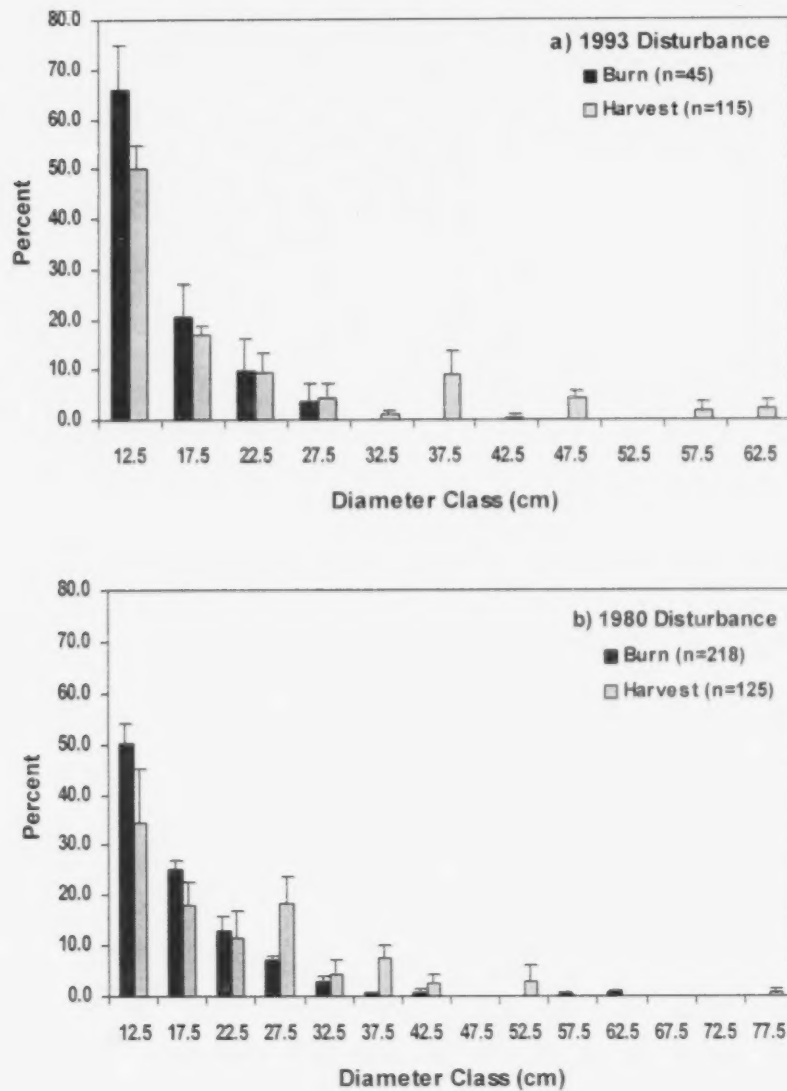


Figure 3.13. Percent of coarse down woody material in burn (N=4) and harvest (N=4) treatments in diameter size categories in a) 1993 and b) 1980 disturbance age-classes of white-spruce dominated stands.

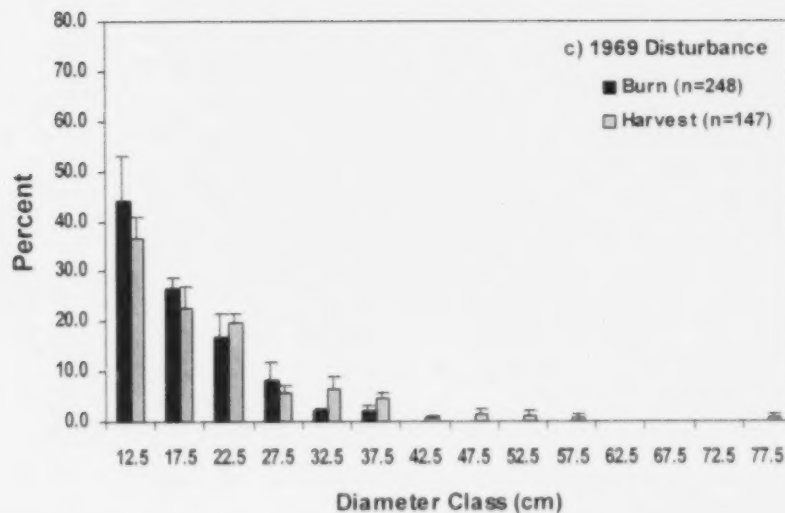


Figure 3.13 continued. Percent of coarse down woody material in burn (N=4) and harvest (N=4) treatments in diameter size categories in c) 1969 disturbance age-classes of white-spruce dominated stands.

Pattern of Decay

The pattern of decay was very similar between the 1993 burn and harvest stands ($F=0.357$, $df=6$, $p=0.901$; Figure 3.14a). In the 1980 and 1969 age-classes (Figure 3.14b and c), the pattern of decay in burn and harvest stands diverged ($F=18.105$, $df=6$, $p<0.000$ and $F=15.995$, $df=6$, $p<0.000$) with a higher percentage of snags in lower decay stages in burn stands. In the 1980 age-class, a greater percentage of coarse DWM was found in decay stages 1 (Mann-Whitney Test; $U_{0.10(2),4,4}=0.081$), 2 ($U_{0.10(2),4,4}=0.021$), and 3 ($U_{0.10(2),4,4}=0.043$) whereas a greater percentage of coarse DWM was found in harvest stands for decay stages 4 ($U_{0.10(2),4,4}=0.021$), 5 ($U_{0.10(2),4,4}=0.021$), and 6 ($U_{0.10(2),4,4}=0.042$). In the 1969 age-class, a greater percentage of coarse DWM was found in decay stages 1 ($U_{0.10(2),4,4}=0.014$), 2 ($U_{0.10(2),4,4}=0.021$), and 3 ($U_{0.10(2),4,4}=0.021$) whereas a greater percentage of coarse DWM was found in harvest stands for decay stages 4 ($U_{0.10(2),4,4}=0.083$), 5 ($U_{0.10(2),4,4}=0.020$), 6 ($U_{0.10(2),4,4}=0.020$), and 7 ($U_{0.10(2),4,4}=0.042$).

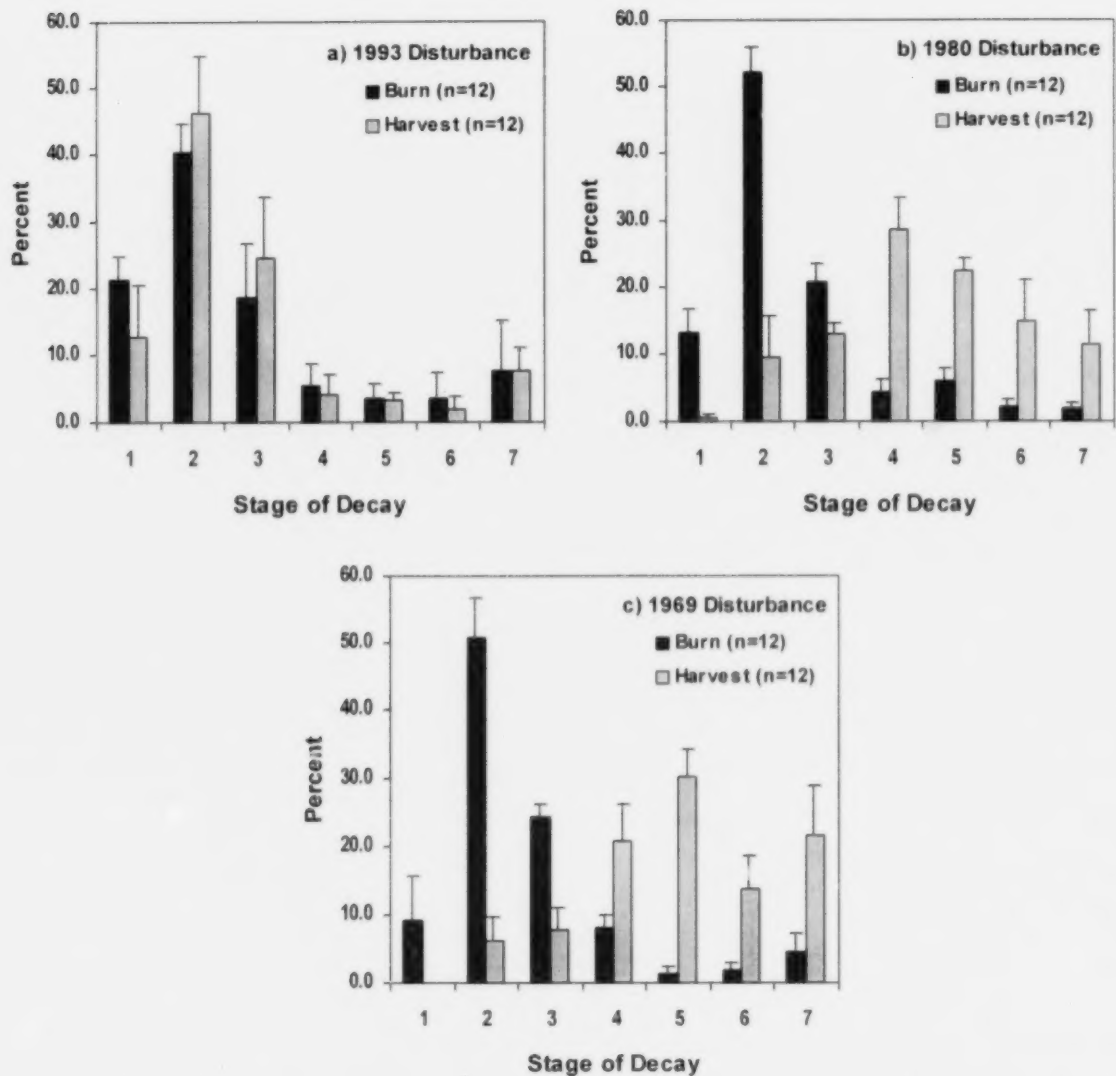


Figure 3.14. Percent of coarse down woody material ($\geq 10\text{cm DBH}$) as grouped by seven stages of decay for burn ($N=4$) and harvest ($N=4$) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes.

3.3.4 Fine and Medium Down Woody Material

In the 1993 age-class, 276 pieces of fine and 34 pieces of medium DWM were sampled in burn stands as compared to 708 and 37 pieces of fine and medium DWM in harvest stands.

In the 1980 burn stands, 369 pieces of fine and 33 pieces of medium DWM were sampled as compared to 493 and 14 fine and medium pieces in the 1980 harvest stands. In the 1969 age-

class, 349 fine and 30 medium pieces of DWM were sampled in burn stands and 189 fine and 23 medium pieces of DWM in harvest stands.

Average frequency of fine DWM in the 1993 age-class was more than twice as great in harvest stands (14.8 ± 4.4 pieces/m) compared to burn stands (5.8 ± 2.0 pieces/m), but was not significantly different due to large variability at the stand level (nested ANOVA; $F=3.394$, $df=1$, $p=0.115$; Figure 3.15a). Frequency of medium DWM was very similar between burn and harvest stands within the 1993 age-class (0.7 ± 0.1 pieces/m and 0.8 ± 0.4 pieces/m, respectively; $F=0.029$, $df=1$, $p=0.871$; Figure 3.15b).

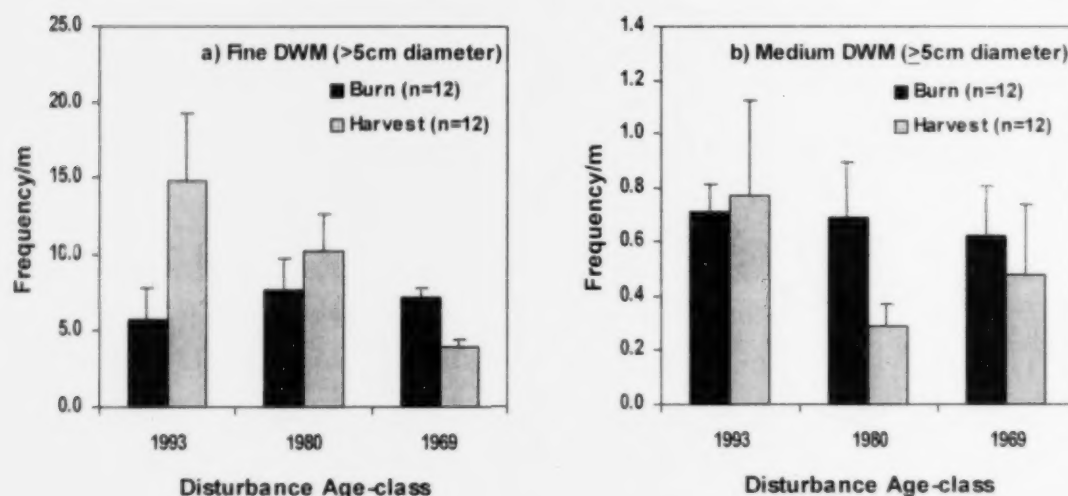


Figure 3.15. Frequency per metre of a) fine and b) medium down woody material in burn ($N=4$) and harvest ($N=4$) treatments in three disturbance age-classes of white spruce-dominated forests.

In the 1980 age-class, fine DWM was only slightly higher in harvest stands (10.7 ± 2.0 pieces/m) than burn stands (7.7 ± 2.1 pieces/m; $F=0.700$, $df=1$, $p=0.435$; Figure 15a). Although frequency of medium DWM was more than twice as high in the burns (0.7 ± 0.2 pieces/m) as compared to harvest stands (0.3 ± 0.1 pieces/m, there was a high degree of variability at the stand level ($F=3.151$, $df=1$, $p=0.126$; Figure 3.15b).

As fine DWM increased with time since disturbance in burn stands (7.3 ± 0.6 pieces/m) and decreased in harvest stands (3.9 ± 0.5 pieces/m), frequency of fine DWM was almost twice as great in burn stands than harvest stands in the 1969 age-class ($F=19.224$, $df=1$, $p=0.005$; Figure 3.15a). The input of medium DWM was a U-shape in harvest stands

whereas frequency of medium DWM remained relatively constant with time since disturbance. As a result, frequency of medium DWM was similar in burn stands (0.6 ± 0.2 pieces/m) as compared to harvest stands (0.5 ± 0.3 pieces/m) in the 1969 age-class ($F=0.206$, $df=1$, $p=0.666$; Figure 3.15b).

3.3.5 Canopy Cover

Percent Cover

In the 1993 age-class, estimates of canopy cover from ground level were only slightly greater in burn stands ($40.9 \pm 2.0\%$) than harvest stands ($37.4 \pm 8.0\%$; nested ANOVA; $F=0.09$, $df=1$, $p=0.770$; Figure 3.16a). At 1.6m above ground, estimates of canopy cover were lower in both treatment types ($12.2 \pm 3.2\%$ in burns and $1.9 \pm 1.3\%$ in harvest stands), but a greater decline occurred in harvest stands making the difference between treatment types significant ($F=14.53$, $df=1$, $p<0.000$).

Canopy cover was greater in the 1980 age-class relative to the 1993 age-class for burn and harvest stands at both ground and 1.6m levels (Figure 3.16a and b). Although increases in percent cover were greater in the harvest treatment, there were no differences between burn and harvest stands for either the ground level position ($57.7 \pm 8.8\%$ in burn and $76.9 \pm 6.1\%$ in harvests; $F=0.003$, $df=1$, $p=0.853$) or the 1.6m position ($37.7 \pm 7.7\%$ in burn and $57.8 \pm 9.8\%$ in harvests; $F=0.03$, $df=1$, $p=0.863$).

In the 1969 age-class, only a slight difference in canopy cover existed between burn ($68.6 \pm 3.3\%$) and harvest ($71.3 \pm 3.6\%$) stands at ground level ($F=0.040$, $df=1$, $p=0.845$; Figure 3.16a). For the 1.6m position, canopy cover was greater in harvest stands ($51.3 \pm 4.5\%$) than burn stands ($40.9 \pm 3.2\%$), but the difference was not significant ($F=2.43$, $df=1$, $p=0.122$; Figure 3.16b).

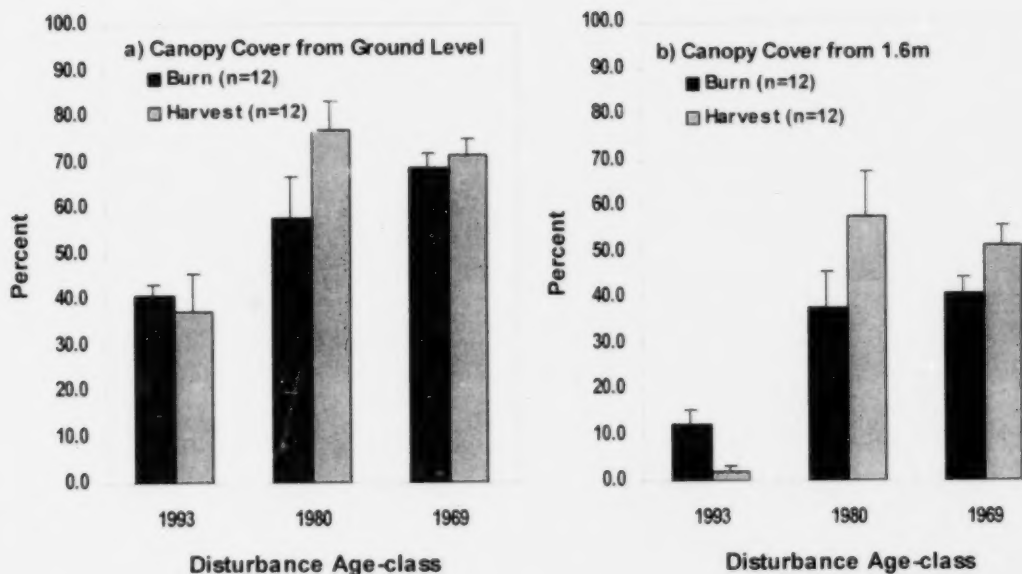


Figure 3.16. Percent of canopy cover for burn (N=4) and harvest (N=4) treatments as measured from two heights a) ground level and b) 1.6m above ground for three disturbance age-classes.

Spatial Pattern of Canopy Cover

None of the treatment types exhibited a significant degree of heterogeneity in canopy cover within stands for either the ground level or 1.6m above ground estimates (Variance Components Analysis; Table 3.5). Differences between burn and harvest treatments in spatial pattern of canopy cover occurred for the 1993 ground level estimate and the 1980 1.6m above ground estimate where spatial pattern was heterogeneous for the harvest and burn treatments, respectively. Otherwise, spatial pattern of canopy cover at the stand level matched between treatment counterparts within an age-class. There was an overall trend for heterogeneity among stands to occur in the 1980 age-classes.

Table 3.5. Variance component analysis on canopy cover as estimated from ground level and 1.6m above ground within and among stands for burn and harvest treatments within the 1993, 1980, and 1969 age-classes.

Treatment	Groundlevel					Treatment	1.6m Height				
	Source	df	MS	F	P		Source	df	MS	F	P
93 Burn	Stand	3	197.74	0.192	0.901	93 Burn	Stand	3	478.30	1.762	0.174
	Site	11	974.01	0.945	0.512		Site	11	213.78	0.787	0.651
	Error	33	1031.08				Error	33	271.48		
93 Harvest	Stand	3	3287.82	2.766	0.058	93 Harvest	Stand	3	86.13	1.540	0.223
	Site	11	2024.64	1.703	0.118		Site	11	61.92	1.107	0.387
	Error	32	1188.58				Error	32	55.92		
80 Burn	Stand	3	3718.75	4.987	0.006	80 Burn	Stand	3	2820.14	2.199	0.107
	Site	11	1235.04	1.656	0.128		Site	11	878.22	0.685	0.743
	Error	33	745.64				Error	33	1282.64		
80 Harvest	Stand	3	1770.14	3.015	0.044	80 Harvest	Stand	3	4631.08	3.192	0.036
	Site	11	840.34	1.431	0.206		Site	11	984.23	0.678	0.748
	Error	33	587.18				Error	33	1450.77		
69 Burn	Stand	3	510.24	0.519	0.672	69 Burn	Stand	3	493.58	0.417	0.742
	Site	11	958.48	0.974	0.488		Site	11	1181.96	0.999	0.468
	Error	33	983.73				Error	33	1183.35		
69 Harvest	Stand	3	658.16	0.672	0.576	69 Harvest	Stand	3	869.18	0.545	0.655
	Site	11	929.81	0.949	0.509		Site	11	1314.70	0.824	0.617
	Error	32	979.83				Error	32	1595.15		

3.3.6 Quadrat Sampling

Saplings

A total of 999 saplings were sampled in the 1993 burns as compared to 247 saplings sampled in the 1993 harvest stands (Figure 3.17a). Overall average abundance of saplings was four times greater in burn stands (249.8 ± 43.0) than in harvest stands (61.8 ± 9.8 ; blocked ANOVA; $F=18.213$, $df=1$, $p=0.005$). Although trembling aspen and balsam poplar were the most common species in both treatment types, relative abundance of species differed between burn and harvest stands ($F=10.485$, $df=7$, $p<0.000$). However, species richness was similar between burn (4.3 ± 0.5) and harvest stands (2.8 ± 0.3 ; Mann Whitney test; $U_{0.10(2),4,4}=0.429$).

In the 1980 age-class, 717 saplings were sampled in burn stands and 131 in harvest stands (Figure 3.17b). Average abundance was five times greater in burn stands (179.3 ± 70.8) as compared to harvest stands (32.8 ± 8.2 ; $F=4.220$, $df=1$, $p=0.086$). Pine saplings were found exclusively in burn stands and were the most abundant species in this treatment. White spruce saplings were most abundant in harvest stands, but no significant difference occurred

in relative abundance between treatments ($F=1.712$, $df=7$, $p=0.132$). Species richness was greater in burn stands (4.5 ± 0.3) than harvest stands (3.3 ± 0.3 ; $U_{0.10(2),4,4}=0.032$).

In the 1969 age-class, 313 sapling species were sampled in burn stands and 229 in harvest stands (Figure 3.17c). The difference in average abundance between burn (78.3 ± 28.9) and harvest (57.3 ± 12.2) stands was not significant ($F=0.448$, $df=1$, $p=0.528$; Figure 3.20). White spruce was the most abundant species in both burn and harvest stands with no difference in the distribution of species abundance ($F=0.740$, $df=7$, $p=0.639$) or species richness (4.8 ± 0.6 and 4.0 ± 1.1 ; $U_{0.10(2),4,4}=0.032$) between the two treatment types.

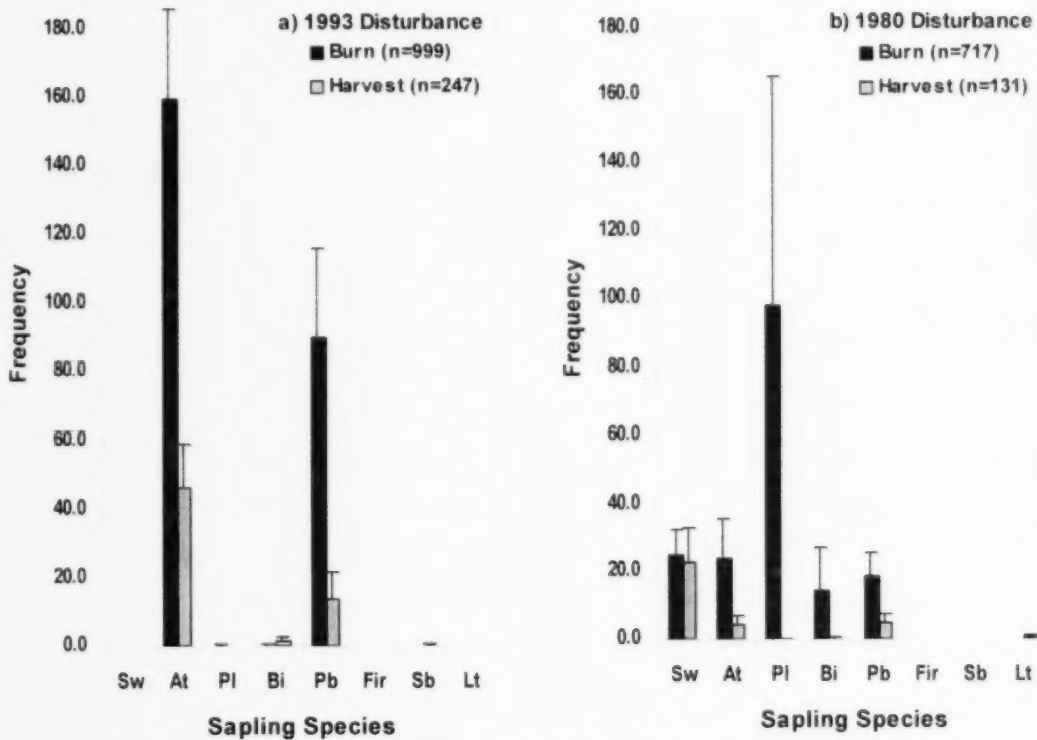


Figure 3.17. Average frequency of sapling species in burn ($N=4$) and harvest ($N=4$) treatments for a) 1993 and b) 1980 disturbance age-classes in white spruce-dominated stands.

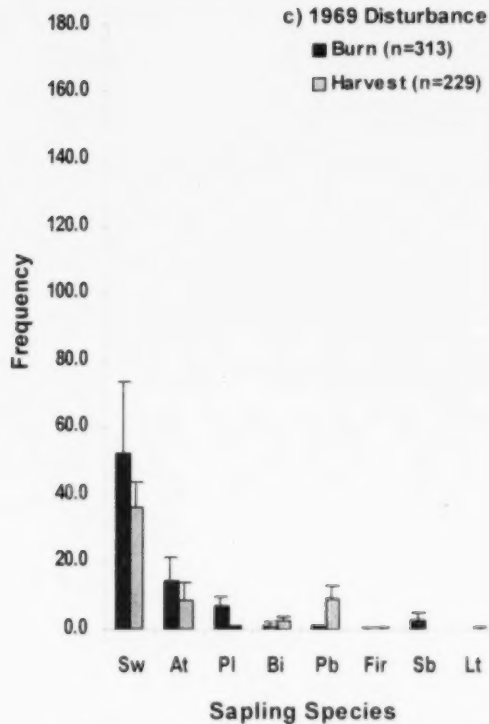


Figure 3.17 continued. Average frequency of sapling species in burn (N=4) and harvest (N=4) treatments for c) 1969 disturbance age-class in white spruce-dominated stands.

Seedlings

A total of 4,512 and 276 seedlings were sampled in the 1993 burn and 1993 harvest stands, respectively (Figure 3.18a). The average number of seedlings was 16 times greater in burn stands ($1,128.0 \pm 372.5$) than in harvest stands (blocked ANOVA; $F=8.066$, $df=1$, $p=0.030$). White spruce and balsam poplar seedlings were the most abundant species in burns, whereas birch and white spruce seedlings were most abundant in harvest stands with relative abundance differing significantly between treatment types ($F=5.613$, $df=7$, $p<0.000$). Species richness was similar between burns and harvests (4.5 ± 0.6 and 3.3 ± 0.6 ; Mann Whitney test; $U_{0.10(2),4.4}=0.180$).

In the 1980 disturbance age-class, 3,503 seedlings were sampled in burn stands and 407 seedlings in harvest stands (Figure 3.18b). Similar to the 1993 age-class, average seedling abundance was much greater in burn stands (875.8 ± 159.8) than in harvest stands (101.8 ± 30.6 ; $F=22.724$, $df=1$, $p=0.003$) and relative abundance among species differed

between treatment types ($F=7.358$, $df=7$, $p<0.000$). Species richness did not differ significantly between burn (4.0 ± 0.7) and harvest stands (2.3 ± 0.6 ; $U_{0.10(2),4,4}=0.106$).

In the 1969 age-class, similar numbers of seedlings were sampled in burn ($n=497$) and harvest ($n=450$) stands with no significant difference in average abundance occurring between treatment types (124.3 ± 42.7 in burns and 112.5 ± 22.0 in harvests; $F=0.60$, $df=1$, $p=0.815$; Figure 3.18c). White spruce seedlings were the most abundant species in burn and harvest stands with no difference in species relative abundance ($F=0.92$, $df=7$, $p=0.999$) or species richness (3.8 ± 0.5 and 3.5 ± 0.6 ; $U_{0.10(2),4,4}=0.765$) between treatment types.

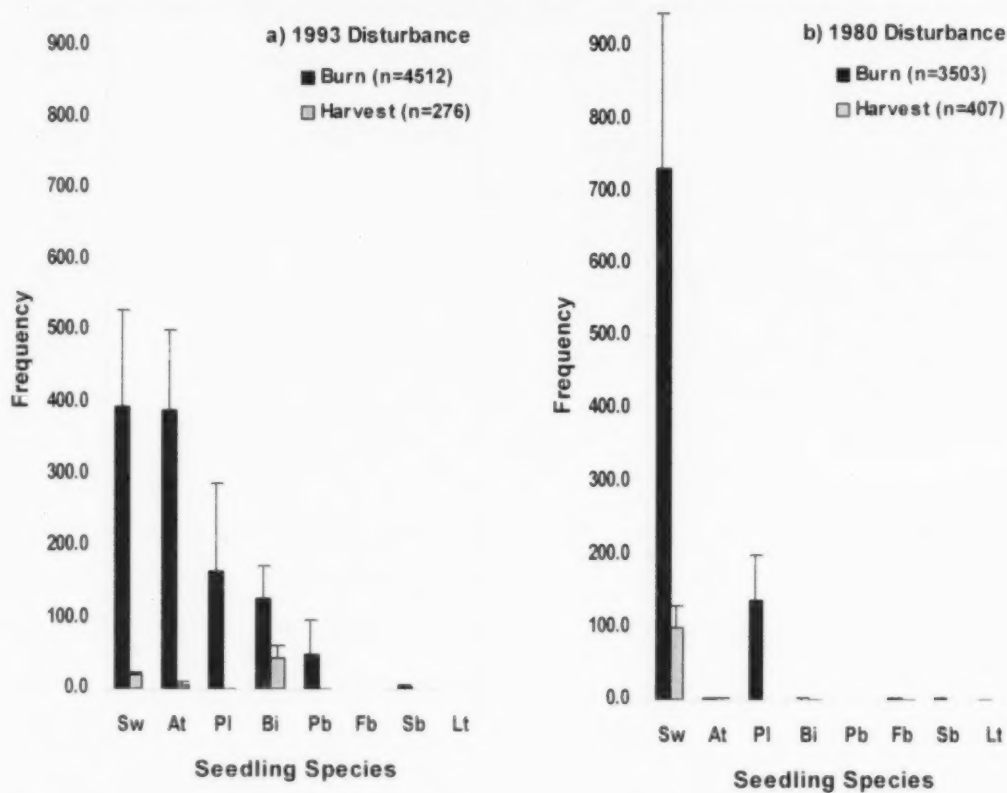


Figure 3.18. Average frequency of seedling species in burn ($N=4$) and harvest ($N=4$) treatments for a) 1993 and b) 1980 disturbance age-classes in white spruce-dominated forests.

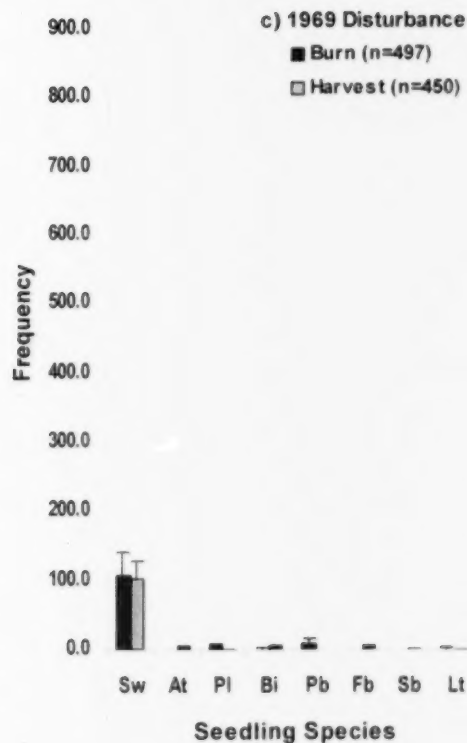


Figure 3.18 continued. Average frequency of seedling species in burn (N=4) and harvest (N=4) treatments for c) 1969 disturbance age-class in white spruce-dominated forests.

Tall Shrubs ($\geq 3m$ in height)

No tall shrubs were found in either the 1993 burn or harvest treatments.

In the 1980 age-class, a total of 121 shrub stems were sampled in burn stands and 268 stems in harvest stands. Average frequency of stems did not differ significantly between burn (30.3 ± 11.8) and harvest stands (67.0 ± 24.5 ; blocked ANOVA; $F=1.832$, $df=1$, $p=0.225$; Figure 3.19a). Willow species were six times more abundant in harvest stands than burn stands, but the abundance of river alder, and bog birch were similar with no significant difference in relative abundance among species ($F=1.201$, $df=2$, $p=0.335$). Species richness was similar between burn (1.8 ± 0.3) and harvest treatments (2.0 ± 0.7 ; Mann Whitney test; $U_{0.10(2),4,4}=0.439$).

In the 1969 age-class, a total of 185 individuals were sampled in the burn stands compared to 53 individuals harvest stands with no significant difference between treatment

types in average frequency (46.3 ± 23.1 in burns and 13.2 ± 7.7 in harvests; $F=1.837$, $df=1$, $p=0.224$; Figure 3.19b). Willows, green alder, and bog birch were more abundant in burn stands than harvest stands with no difference in relative abundance among species occurring between treatment types ($F=1.241$, $df=2$, $p=0.324$). The number of species was similar between burn (1.8 ± 0.5) and harvest stands (1.0 ± 0.0 ; $U_{0.10(2),4,4}=0.439$).

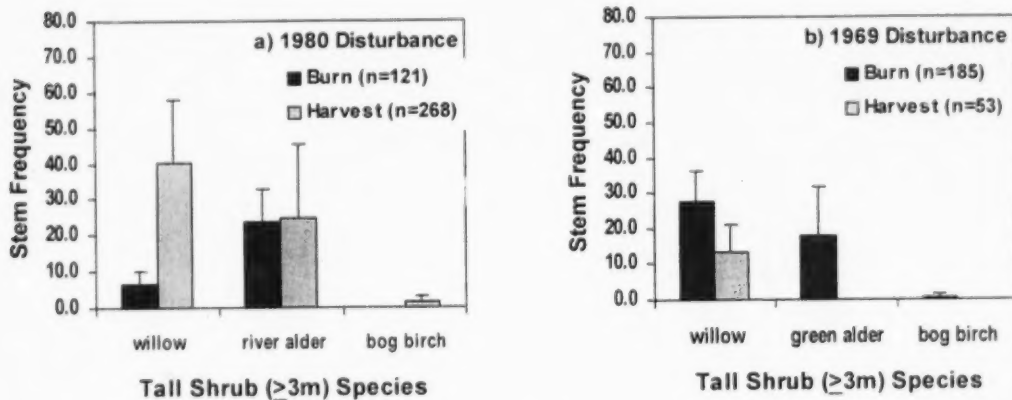


Figure 3.19. Average number of tall shrub stems ($\geq 3m$ in height) for each species for burn ($N=4$) and harvest ($N=4$) treatments in a) 1980 and b) 1969 disturbance age-classes in white spruce-dominated stands.

Mid Shrubs ($\geq 1m$ and $< 3m$ in height)

In the 1993 age-class, total stem frequency of shrubs was greater in the burn stands with a stem frequency almost three times greater in burn stands (88.0 ± 2.3) than in harvest stands (30.8 ± 6.3 ; $F=72.734$, $df=1$, $p<0.000$; Figure 3.20a). Species richness of mid shrubs was greater in harvest stands (4.0 ± 0.6) than burn stands (2.5 ± 0.3 ; Mann Whitney test; $U_{0.10(2),4,4}=0.061$). Willow species were ten times more abundant in burn stands than in harvest stands, whereas wild rose and willow were the dominant species in harvest stands. Relative abundance of species differed between treatment types ($F=37.691$, $df=5$, $p<0.000$).

Species richness was greatest in the 1980 age-class with more species occurring in the harvest stands (8.3 ± 0.9) as compared to the burn stands (5.5 ± 0.5 ; $U_{0.10(2),4,4}=0.046$; Figure 3.20b). Willow was the dominant species in both burns and harvests with no significant difference in relative abundance between treatment types ($F=1.930$, $df=14$, $p=0.196$). Total

abundance of shrub stems was also similar between burn (224.3 ± 28.7) and harvest treatments (191.0 ± 37.1 ; $F=0.503$, $df=1$, $p=0.505$).

In the 1969 age-class, the number of species was greater in burn stands (6.3 ± 0.3) than harvest stands (4.3 ± 0.5 ; $U_{0.10(2),4,4}=0.017$; Figure 3.20c). Willow and lowbush cranberry were the dominant species in burn stands and willow was the most abundant species in harvest stands. No significant difference occurred in relative abundance of species between treatment types ($F=0.850$, $df=7$, $p=0.553$). Although mid shrub abundance was greater in burn stands (128.5 ± 24.4) than in harvest stands (79.5 ± 30.0), there was no difference between the two treatments types ($F=0.1606$, $df=1$, $p=0.252$).

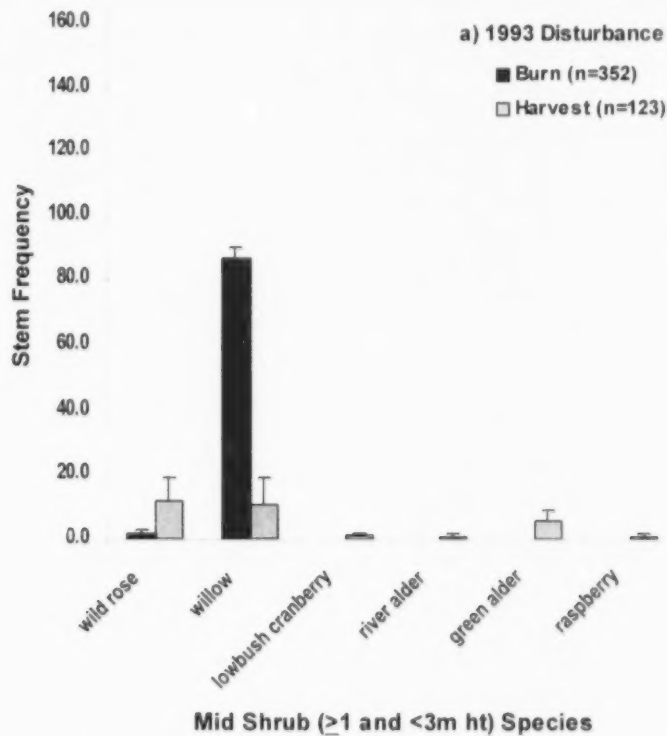


Figure 3.20. Average number of mid shrub stems (≥ 1 m and < 3 m in height) per species for burn ($N=4$) and harvest ($N=4$) treatments in a) 1993 disturbance age-class in white spruce-dominated stands.

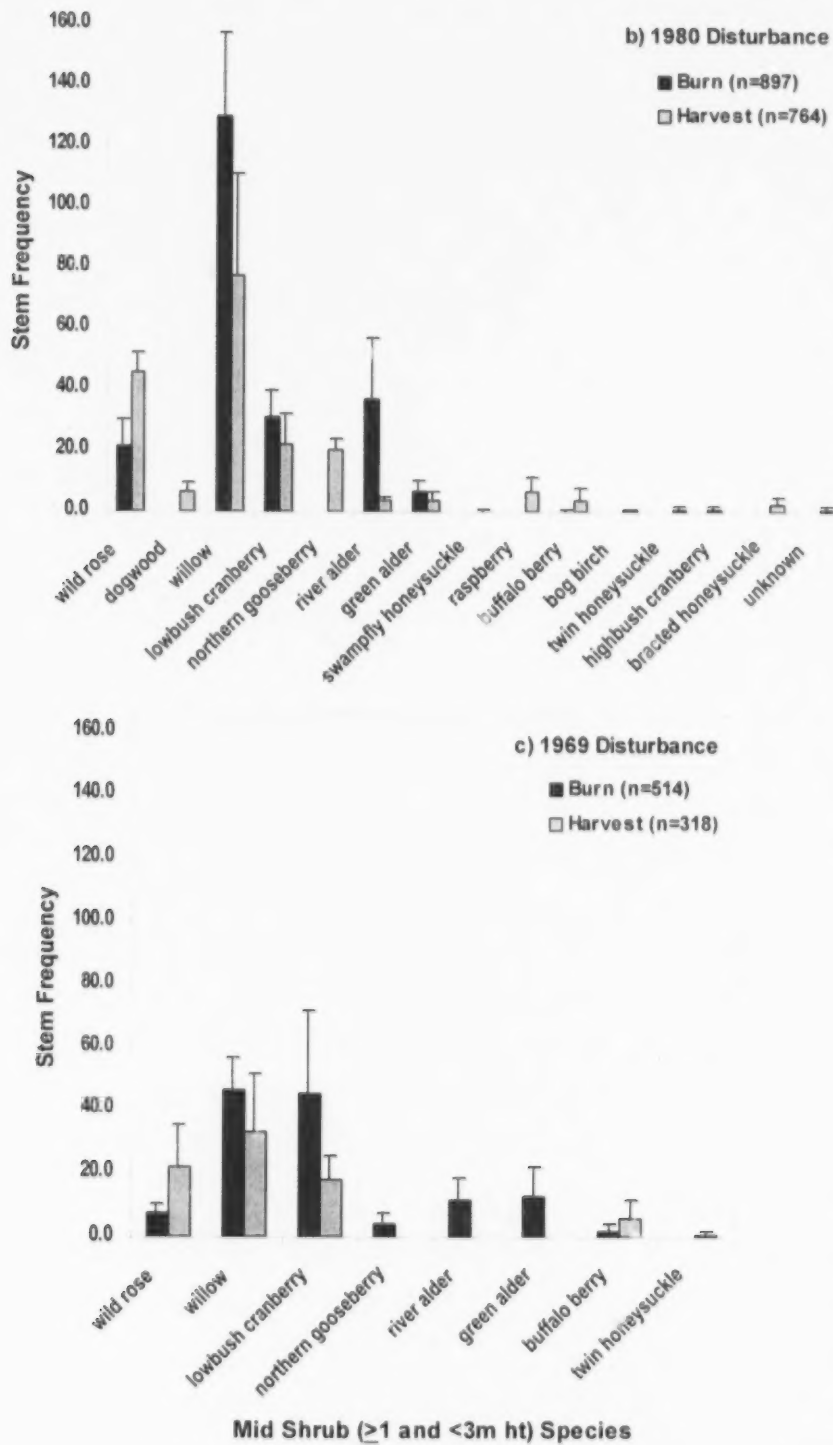


Figure 3.20 continued. Average number of mid shrub stems (≥ 1 m and < 3 m in height) per species for burn ($N=4$) and harvest ($N=4$) treatments in b) 1980 and c) 1969 disturbance age-classes in white spruce-dominated stands.

Low Shrubs (height < 1m)

In the 1993 age-class, a total of ten species of shrubs were identified. Species richness was very similar between burn (4.0 ± 0.9) and harvest treatments (4.8 ± 0.5 ; Mann Whitney test; $U_{0.10,4,4} = 0.557$; Figure 3.21a). Incidence of occurrence differed between treatment types for four species. Willow and dwarf blueberry occurred more frequently in burn stands (Mann Whitney test; $U_{0.10,4,4} = 0.017$ and $U_{0.10,4,4} = 0.046$, respectively) whereas northern gooseberry and raspberry were more common in harvest stands ($U_{0.10,4,4} = 0.046$ and $U_{0.10,4,4} = 0.018$).

Of the 19 shrub species occurring in the 1980 age-class, almost equal numbers of species were found in the burn (7.8 ± 0.6) and harvest stands (7.3 ± 1.4 ; $U_{0.10,4,4} = 1.000$; Figure 3.21b). Incidence of occurrence differed between treatment types with Labrador tea occurring exclusively in burns ($U_{0.10,4,4} = 0.047$) whereas wild rose and northern gooseberry occurred more frequently in harvest stands ($U_{0.10,4,4} = 0.078$ and $U_{0.10,4,4} = 0.082$, respectively).

In the 1969 age-class, species richness was similar between burn (6.5 ± 0.9) and harvest stands (5.5 ± 0.9 ; $U_{0.10,4,4} = 0.234$; Figure 3.21c). Occurrence of species did not differ significantly between treatment types ($F = 0.422$, $df = 11$, $p = 0.941$).

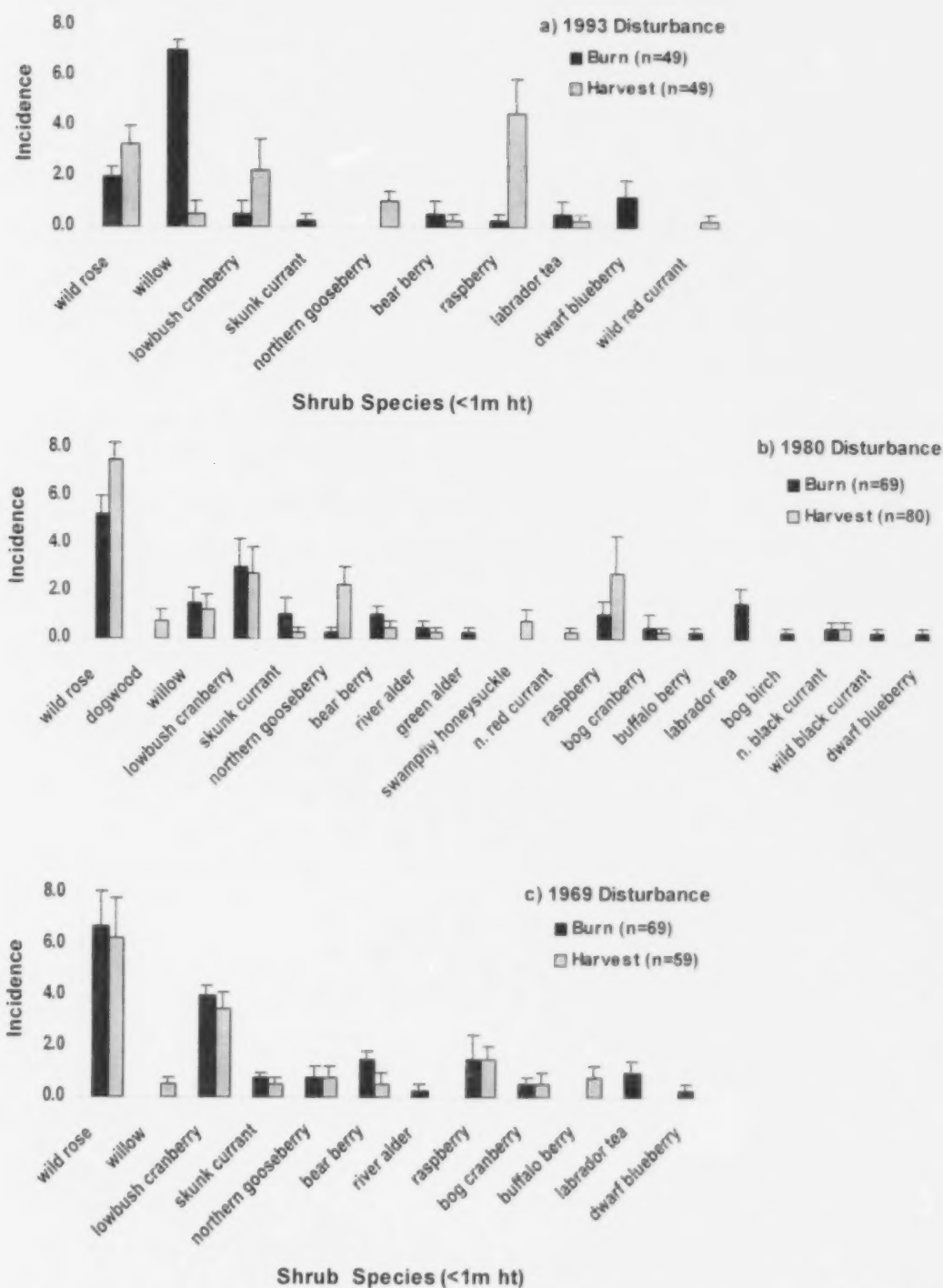


Figure 3.21. Average incidence of occurrence for shrub species in burn (N=4) and harvest (N=4) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes. Incidence was determined by the number of times a species was recorded in each of twelve plots sampled in each treatment stand. n is total number of occurrences for all species.

Herb Diversity

In the 1993 age-class, a total of 41 herb species were found in burn stands and 33 species in harvest stands, but no difference in species richness was found between the two treatment types (Mann Whitney test; $U_{0.10,4,4}=1.000$). The composition of species was different between treatment types (blocked ANOVA; $F=3.309$, $df=48$, $p<0.000$) with differences occurring for five species. The incidence of bishop's cap, tall lungwort, and sweetscented bedstraw was greater in harvest stands whereas American vetch and bicnell's geranium were found exclusively in burn stands (Mann Whitney test; $U_{0.10,4,4}$; Table 3.6).

In the 1980 age-class, 35 species were sampled in the burn stands as compared to 38 species in the harvest stands ($U_{0.10,4,4}=0.386$). Species composition differed significantly between treatment types ($F=3.143$, $df=48$, $p<0.000$). Incidence of occurrence for bunchberry, palmate-leaved coltsfoot, purple peavine, twinflower and American vetch was greater in burns whereas tall lungwort, meadow horsetail, and wild sarsaparilla occurred more often in harvest stands (Table 3.6).

The lowest number of herb species was found in the 1969 age-class with 32 species found in burns and 22 species in harvest stands ($U_{0.10,4,4}=0.248$). Similarly to the 1993 and 1980 age-classes, species composition differed between treatment types ($F=2.544$, $df=33$, $p<0.000$). Incidence of occurrence differed between treatment types for six species with a higher incidence of bunchberry, kidney-leaved violet, woodland horsetail, and sweet-scented bedstraw in the burns and a higher incidence of dewberry and northern bedstraw in harvest stands (Table 3.6).

Table 3.6. Mean incidence (S.E.) of herbs by treatment type. Value denotes significance level of incidence between treatment types within an age-class as tested by Mann Whitney test with tied ranks. NS indicates no change between treatment types.

Common Name	93 Burn	93 Harvest	value	80 Burn	80 Harvest	value	69 Burn	69 Harvest	value
Dwarf lungwort	0.75 ± 0.75	1.00 ± 1.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.25 ± 0.25	0.25 ± 0.25	NS
Fireweed	7.00 ± 1.68	7.75 ± 1.11	NS	5.75 ± 0.75	4.75 ± 0.85	NS	7.00 ± 0.82	7.75 ± 1.11	NS
Bunchberry	5.50 ± 0.29	4.75 ± 0.48	NS	9.50 ± 0.87	5.00 ± 0.82	0.027	10.75 ± 0.63	6.25 ± 0.48	0.019
Palmate-leaved coltsfoot	1.75 ± 0.85	1.25 ± 0.25	NS	5.00 ± 1.22	1.25 ± 0.48	0.037	3.25 ± 0.85	4.00 ± 0.71	NS
Bishop's cap	0.25 ± 0.25	3.25 ± 0.63	0.017	3.50 ± 0.29	3.25 ± 1.31	NS	3.75 ± 1.11	2.50 ± 0.65	NS
Tall lungwort	1.25 ± 0.63	4.00 ± 1.22	0.080	2.50 ± 0.50	4.00 ± 0.71	0.099	4.00 ± 1.08	5.75 ± 1.03	NS
Purple peavine	0.50 ± 0.50	0.25 ± 0.25	NS	2.75 ± 0.85	0.75 ± 0.48	0.078	1.25 ± 0.75	0.75 ± 0.48	NS
Twin-flower	2.00 ± 0.91	2.75 ± 1.44	NS	7.25 ± 0.48	3.75 ± 1.31	0.028	6.00 ± 1.08	4.50 ± 1.19	NS
Creamy peavine	0.00 ± 0.00	0.50 ± 0.29	NS	0.75 ± 0.48	1.00 ± 0.58	NS	1.00 ± 0.41	1.50 ± 0.96	NS
Kidney-leaved violet	1.25 ± 0.95	1.00 ± 0.71	NS	3.00 ± 1.29	1.50 ± 0.50	NS	4.00 ± 0.71	1.50 ± 0.96	0.076
Woodland horsetail	6.75 ± 1.70	4.00 ± 1.08	NS	6.00 ± 1.58	3.50 ± 1.04	NS	6.00 ± 1.15	3.50 ± 0.50	0.096
Common horsetail	2.75 ± 0.85	1.25 ± 0.63	NS	2.00 ± 1.08	6.75 ± 2.32	NS	1.00 ± 1.00	1.25 ± 0.63	NS
Meadow horsetail	0.00 ± 0.00	0.50 ± 0.29	NS	0.25 ± 0.25	1.00 ± 0.00	0.040	0.00 ± 0.00	0.00 ± 0.00	NS
Sweet-scented bedstraw	0.00 ± 0.00	1.50 ± 0.87	0.046	0.75 ± 0.48	1.25 ± 0.75	NS	1.50 ± 0.50	0.25 ± 0.25	0.040
Dewberry	1.75 ± 1.18	3.50 ± 1.04	NS	3.25 ± 0.48	3.25 ± 0.48	NS	2.75 ± 0.48	4.75 ± 0.48	0.037
Small enchanters nightshade	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Wild sarsaparilla	0.00 ± 0.00	0.50 ± 0.50	NS	0.00 ± 0.00	1.25 ± 0.48	0.046	0.00 ± 0.00	0.00 ± 0.00	NS
Wild strawberry	0.25 ± 0.25	1.00 ± 0.58	NS	1.00 ± 0.71	1.75 ± 0.75	NS	1.00 ± 0.41	0.75 ± 0.48	NS
Three-leaved false solomon's-seal	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.25 ± 0.25	NS
Marsh violet	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Common dandelion	3.00 ± 1.22	1.75 ± 0.85	NS	0.00 ± 0.00	0.50 ± 0.29	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Canada anemone	4.00 ± 1.78	1.75 ± 0.25	NS	1.00 ± 0.71	0.50 ± 0.29	NS	1.25 ± 0.75	2.00 ± 0.41	NS
Early blue violet	0.25 ± 0.25	0.50 ± 0.29	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.25 ± 0.25	0.25 ± 0.25	NS
Common yarrow	0.00 ± 0.00	0.50 ± 0.29	NS	0.00 ± 0.00	0.75 ± 0.75	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Dwarf scouring brush	0.75 ± 0.75	0.50 ± 0.29	NS	0.75 ± 0.48	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Bog cranberry	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Woodland strawberry	1.50 ± 0.50	1.75 ± 1.75	NS	1.25 ± 0.95	0.75 ± 0.25	NS	0.50 ± 0.29	1.00 ± 0.41	NS
Purple-leaved willow herb	1.00 ± 0.41	1.75 ± 1.11	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Narrow-leaved hawkweed	2.50 ± 1.32	1.00 ± 0.71	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Cloudberry	0.50 ± 0.50	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Western Canada violet	0.75 ± 0.48	0.25 ± 0.25	NS	0.50 ± 0.29	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
American vetch	3.50 ± 1.50	0.00 ± 0.00	0.046	1.50 ± 0.50	0.00 ± 0.00	0.040	0.25 ± 0.25	0.50 ± 0.50	NS
Cow wheat	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Arrow-leaved coltsfoot	0.50 ± 0.50	0.00 ± 0.00	NS	0.25 ± 0.25	0.25 ± 0.25	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Canadian milk vetch	0.75 ± 0.48	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Leafy amica	0.00 ± 0.00	0.00 ± 0.00	NS	0.50 ± 0.29	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Bracted Lousewort	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.25 ± 0.25	NS
Greenish-flowered wintergreen	0.00 ± 0.00	0.25 ± 0.25	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
One-flower wintergreen	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Common pink wintergreen	0.00 ± 0.00	0.00 ± 0.00	NS	0.75 ± 0.75	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS
One-sided winter green	0.50 ± 0.29	0.00 ± 0.00	NS	0.75 ± 0.25	0.50 ± 0.29	NS	0.25 ± 0.25	0.00 ± 0.00	NS
Northern bedstraw	1.50 ± 0.65	1.50 ± 0.96	NS	0.25 ± 0.25	1.50 ± 0.96	NS	0.00 ± 0.00	2.00 ± 0.58	0.013
Northern green bog orchid	0.25 ± 0.25	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Reflexed locoweed	0.00 ± 0.00	0.00 ± 0.00	NS	0.50 ± 0.50	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS

Table 3.6 continued. Mean incidence (S.E.) of herbs by treatment type. Value denotes significance level of incidence between treatment types within an age-class as tested by Mann Whitney test with tied ranks. NS indicates no change between treatment types.

Common Name	93 Burn	93 Harvest	value	80 Burn	80 Harvest	value	69 Burn	69 Harvest	value
Blunt-leaved sand wort	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Northern grass of parnasis	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.50 ± 0.50	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Tall larkspur	0.00 ± 0.00	0.00 ± 0.00	NS	0.50 ± 0.50	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Marsh skull cap	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Yellow marsh marigold	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Purple stem aster	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Lesser wintergreen	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Marsh hedge nettle	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Bracted bog orchid	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Alsike clover	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Long-leaved chickweed	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.75 ± 0.48	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Wild lily of the valley	1.00 ± 0.71	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Stinging nettle	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Bicnells geranium	2.50 ± 1.19	0.00 ± 0.00	0.047	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Cutleaved anemone	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Common scouring brush	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Round-leaved orchid	1.25 ± 0.95	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Spear-leaved amica	2.00 ± 1.22	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Heart-leaved amica	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Alpine amica	0.50 ± 0.50	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Canada thistle	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Smooth flee bane	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Scentless camomile	0.25 ± 0.25	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Marsh willow herb	0.00 ± 0.00	0.50 ± 0.29	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Phyladelphina flee bane	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Indian hemp	0.00 ± 0.00	0.25 ± 0.25	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS
Nodding chickweed	0.00 ± 0.00	0.00 ± 0.00	NS	0.00 ± 0.00	0.00 ± 0.00	NS	0.25 ± 0.25	0.00 ± 0.00	NS

Percent Cover

Percent cover for shrubs (<1m in height), herbs, grasses, moss, soil, rock, water, wood, and litter was recorded for twelve 50x50cm quadrat per. No rock coverage occurred in any of the samples.

In both the 1993 and 1980 age-classes, the only significant difference in cover types was moss (nested ANOVA; $F=7.751$, $df=1$, $p=0.032$ and $F=5.611$, $df=1$, $p=0.056$, respectively) with five times greater coverage in the 1993 burns and four times greater coverage in the 1980 burns as compared to harvest stands (Figure 3.22a and b).

In the 1969 age-class, percent cover differed significantly for both shrubs and grasses ($F=15.169$, $df=1$, $p=0.008$ and $F=17.319$, $df=1$, $p=0.006$, respectively). Percent cover for shrubs was 1.5 times greater in burns stands than harvest stands, whereas percent cover of grasses was 4.1 times greater in harvest stands than burn stands (Figure 3.22c).

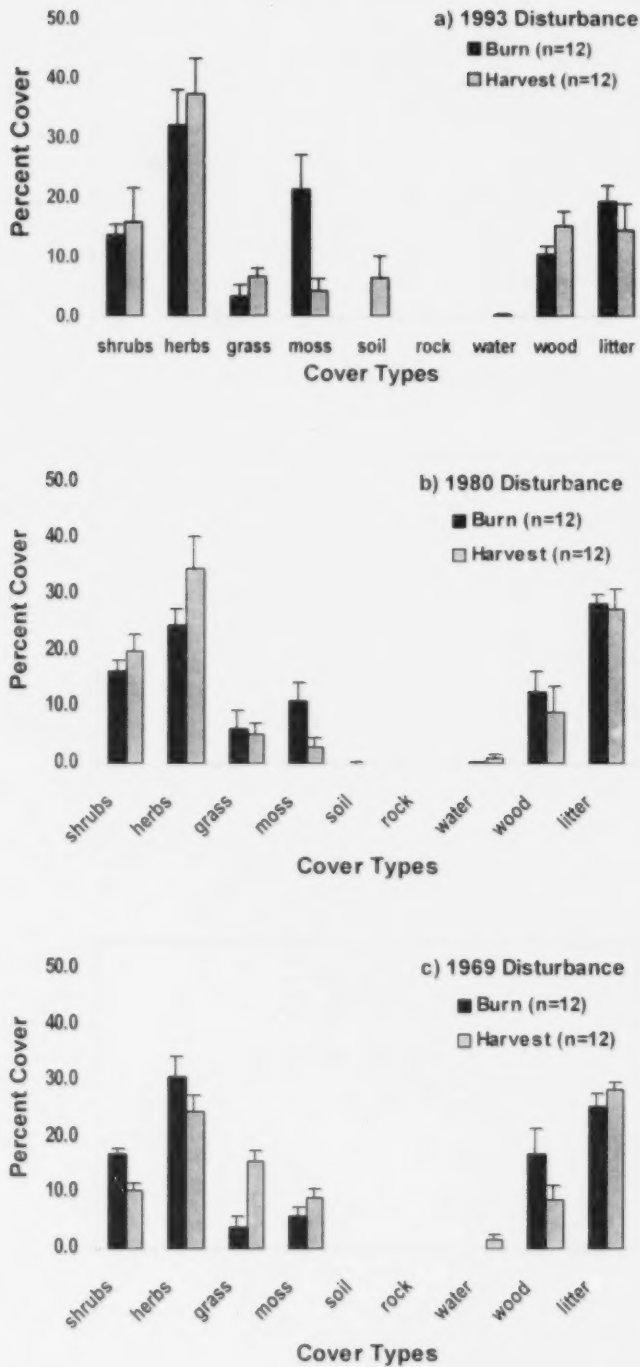


Figure 3.22. Average percent ground cover eight cover types in burn (N=4) and harvest (N=4) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes of white spruce-dominated stands.

3.3.7 Duff Layer

In the 1993 age-class, average duff layer depth was almost twice as deep in harvest stands (7.0 ± 1.1 cm) than in burn stands (4.0 ± 0.6 cm; nested ANOVA; $F=602.372$, $df=1$, $p=0.031$; Figure 3.23). For both the 1980 and 1969 age-classes, there was little difference in the duff layer depth between burns and harvests ($F=0.823$, $df=1$, $p=0.690$ and $F=0.544$, $df=1$, $p=0.776$, respectively).

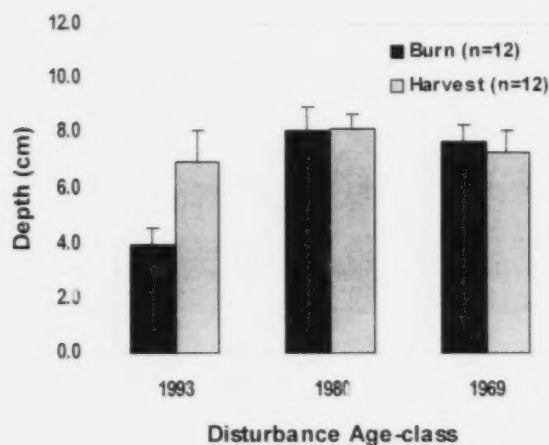


Figure 3.23. Average depth of duff layer in burn ($N=4$) and harvest ($N=4$) treatments in 1993, 1980, and 1969 disturbance age-classes in white-spruce-dominated stands.

3.4 Discussion

Forest structure and composition differed in many aspects between burn and harvest stands in white spruce-dominated forests. Although some of the greatest differences occurred with those structures that were directly related to forest harvesting, there were some surprising similarities as well. It was generally assumed that differences would remain the same or converge with time. In some instances, divergence occurred. Although differences between burn and harvest stands were small for some forest attributes, it was evident that the overall forest community was affected by harvesting as compared to natural burns.

It is important to highlight that the following suggestions for harvest management were based on the assumption that "nature knows best". It is common for anthropomorphic perspectives to assume that more is better. This cannot be the case with a natural disturbance approach to forest management. The underlying premise of this management approach is that

we understand little about the complex interactions of a forest community, therefore we will follow it's example rather than attempt to unravel it's complexities.

Considerations for safety, logistics, and economics will be left up to forest companies. Integrating these factors will possibly cause forest managers to deviate from the natural disturbance template in at least some areas. In doing so, the ramifications of such deviations must be considered as well as their indirect effects on other aspects of the natural disturbance model.

Because each component of the forest has a bearing on some other component, it is difficult to make recommendations for each forest attribute without confounding a dependent attribute. For this reason, to apply a management recommendation out of context would be committing an injustice to the use of a natural disturbance approach to forest management. Although each attribute is discussed on it's own, references to the impact on other attributes are equally important when applying this management strategy.

The following discussion will focus on those attributes that realistically could be manipulated by forest companies. These include large diameter trees, snags, down woody material, and seedlings. When a range is given, it is intended as another guideline to follow, not just a minimum that should be met. The variability within a single forest attribute could be as important to maintaining diversity as ensuring each different forest attribute is maintained. The information gathered on the remaining forest attributes was used to determine if there were differences between harvest and burn stands. Although difficult to manipulate, these data will hopefully provide useful information for monitoring the success of a natural disturbance approach to forest management in the future.

Large diameter trees

Density of large diameter trees was very low in both burn and harvest treatments in the 1993 disturbance age-class. In boreal forests of Alberta, Eberhart and Woodard (1987) also found it unlikely that fires between 20-40ha in size had any live trees remaining within the perimeter. Although tree density increased in both burn and harvest stands as time from disturbance increased, the increase in harvest stands was much greater. This increase in tree density in harvest stands could be linked to measures taken by harvest companies to ensure that regrowth occurred quickly such as planting with three year old seedlings, site

preparation, and application of herbicides. These measures were taken in the 1993 harvest stands and visual inspection of the 1980 and 1969 stands by a forest officer confirmed that these sites were prepared and replanted.

This excess in tree density relative to burn stands gives flexibility to the forest companies. For example, these trees could be used to compensate for low densities of snags found in harvest stands. For this reason, it may be prudent for harvest management to deviate from the natural disturbance template and continue to maintain live trees at the harvest site in their present numbers.

To more closely mimic fire disturbance, green trees retained at the time of harvesting should be clumped among harvest sites and within these sites. Although the low sampling numbers did not allow for statistical analysis of spatial patterns, it can be estimated that trees should be clumped within one of every four harvest stands. If a grid of points were laid on this harvest stand at 40m intervals, all trees should be clumped around 25% of these points.

Under present harvest strategies, harvest stands appear to have, according to the natural disturbance template, a proper size distribution of large diameter trees retained at the time of harvest. However, divergence does occur by the 1980 age-class with average diameter increasing in burn stands to twice that found in harvest stands.

The following guidelines are recommended for applying a natural disturbance approach to forest management at the time of harvesting in a white spruce-dominated forest in Alberta:

- ◆ average density of large diameter trees should be 1.8 ± 0.5 trees/ha with a range of 0.9 to 2.6 trees/ha at a stand level.
- ◆ average diameter of trees should be 21.4 ± 2.8 cm with a distribution of trees in the following diameter categories:
 - 21 to 63% in 10.0 to 14.9cm DBH
 - 14 to 32% in 15.0 to 19.9cm DBH
 - 0 to 18% in 20.0 to 24.9cm DBH
 - 4 to 13% in 25.0 to 29.9cm DBH
 - 0 to 25% in 30.0 to 34.9cm DBH
 - 0 to 13% in 35.0 to 39.9cm DBH
 - 0 to 6% in 40.0 to 44.9cm DBH
 - 0% in 45.0 to 49.9cm DBH
 - 0% in 50.0 to 54.9cm DBH

- 0 to 5% in 55.0 to 59.9cm DBH
 - 0% in 60.0 to 64.9cm DBH
 - 0% in 65.0 to 69.9cm DBH
 - 0% in 70.0 to 75.9cm DBH
 - 0 to 4% in 85.0 to 89.9cm DBH
- ◆ the spatial distribution of trees should be such that trees are clumped into one of every four stands. Within a stand, trees should be clumped around 25% of the points on an imaginary grid with points at 40m intervals.
 - ◆ species distribution should be within the following distribution; 60% white spruce, 10% lodge pole pine, and 30% black spruce.

Large Diameter Snags

Naturally, one of the greatest differences between treatment types was the relatively high density of large diameter snags in burn stands. The lowest snag density measured in a 1993 burn stand was 189.5 snags/ha compared to the highest snag count in a 1993 harvest stand of 3.9 snags/ha. For economical reasons, it would be impractical for forest companies to match the snag densities found in burn stands. However, as time from disturbance reaches 27 years, maintaining an average snag density of 2.4 ± 0.6 snags/ha at the time of harvest would be sufficient to maintain snag densities at levels found in comparable burn stands. Although convergence occurred in terms of snag densities, concern remains for snag densities before convergence given the role snags play in the lives of bird (Conway and Martin 1993; Zarnowitz and Manuwal 1985) and small mammal species (Corn *et. al.* 1988; McDonald 1995).

As is already well known, any snags that a harvest company can safely retain at the harvest site would be valuable, but other sources of snags are needed. The profile of large diameter trees was such that there were a greater number of large diameter trees in harvest stands than in burn stands. In fact, by the time 16 years had passed since the disturbance event, harvest stands had an excess of approximately 18 trees/ha on average. If these trees can be considered to contribute to structure in place of snags, or more drastically, if these trees could be killed at 16 years post-disturbance, the 1980 snag scenario could be improved.

This addition of snags would bring the snag count average to 22 snags/ha in harvest stands as compared to the average of 49.5 ± 15.9 snags/ha in burn stands; a value that would surpass the lowest snag density found in one of the 1980 burn stands (9.7 snags/ha).

Unlike large diameter trees, snags were spatially homogenous within stands for all age-classes. As time from disturbance increased, spatial distribution of snags among burn stands became spatially clumped whereas snags in harvest stands remained spatially homogenous. This would be a difficult attribute to manage for unless there were an addition of snags at some time post-disturbance. If trees were killed to contribute to snag densities, it might be possible to plan for a clumped distribution of tree death depending on tree diameter and location.

The size distribution of snags in harvest stands was well matched to that of the burn stands in the 1993 disturbance age-class. Divergence occurred with a relative decrease in snag diameter in burn stands as time from disturbance increased. As with spatial pattern of snags, this also would be a difficult feature to manage for without removing large diameter snags at some time after harvesting has taken place. Given the difficulties in maintaining snag densities at natural disturbance levels, this would be a poor option. Another option would be to kill the "excess" trees at a time before 16 years post-harvest. Given less time to mature, this would likely lower the average diameter of the trees contributing to snag densities, with the benefit of adding snags to the system at an earlier date after disturbance.

Cavity density in snags was greater in burn stands than harvest stands in the 1993 disturbance age-class, but converged after 16 years from the disturbance event. In order to maintain cavity densities in the 1993 harvest stands, artificial nest boxes would have to be used. However, addition of nest boxes could result in other problems. In a study examining nest predation for several bird species (Nilsson 1984), nest boxes were found to have different predation rates than natural cavities depending on the bird species. The results of this study stress the importance of mimicking the characteristics of natural cavities. Furthermore, providing nest boxes may simply provide nesting sites in poor quality habitat where survival and reproduction would remain low (Lidicker 1975). Hopefully, incorporation of the other harvest recommendations would increase the habitat quality to natural disturbance levels. If not, the presence of unsuccessful breeders due to the presence

of nest boxes in harvested sites could confound results of a monitoring study making it appear that natural disturbance as an approach to forest management was successful.

Snags tended to be in a higher decay class in harvest stands compared to burn stands. The process of burning wood appears to harden the wood and perhaps slow decay. Once again increasing snag density via newly killed trees at a given time after disturbance would skew the snag population to a lower decay class and thus closer to those occurring in a naturally disturbed forest.

The following guidelines are recommended for maintaining snag densities in accordance with a natural disturbance approach to forest management:

- ◆ ideally, average density of large diameter snags should approximate 285.7 snags/ha with a range of 189.5 to 385.2 snags/ha. If harvest companies can maintain an average snag density of 2.4 snags/ha with a range of 1.4 to 3.9 snags/ha, additional snags must be cultivated by killing large diameter trees within 16 years post-harvest. Addition of snags to the system should average a minimum of 22 snags/ha.
- ◆ at the stand level, average snag diameter should be 17.9 ± 1.8 cm DBH. The distribution of snags should fall within the following diameter categories with a range of 10.0 to 56.0 cm DBH:
 - 23 to 70% in 10.0 to 14.9 cm DBH
 - 20 to 34% in 15.0 to 19.9 cm DBH
 - 6 to 17% in 20.0 to 24.9 cm DBH
 - 3 to 12% in 25.0 to 29.9 cm DBH
 - 0 to 13% in 30.0 to 34.9 cm DBH
 - 0 to 5% in 35.0 to 39.9 cm DBH
 - 0 to 3% in 40.0 to 44.9 cm DBH
 - 0 to 4% in 45.0 to 49.9 cm DBH
 - 0 to 1% in 50.0 to 54.9 cm DBH
 - 0 to 1% in 55.0 to 59.9 cm DBH
- ◆ the spatial distribution of snags should be homogenous at the time of harvest both among stands and within stands.
- ◆ at the time of harvest, cavity density among stands should range from 0 to 4.3 cavities/ha with an average of 2.7 ± 0.9 cavities/ha. Since no cavities were found in harvest stands, nest boxes equaling this density would have to be installed. Nest boxes should be removed at a time prior to 16 years post-harvest.

- ◆ species distribution of snags should be within the following distribution; 57 to 68% white spruce, 0 to 14% lodge pole pine, 20 to 33% trembling aspen, 0 to 27% balsam poplar, and 0 to 23% black spruce.

Coarse Down Woody Material

Contrary to expected, there were few differences in the volume of coarse down woody material between burn and harvest stands. In fact, there was a higher volume of coarse DWM in 1993 harvest stands relative to burn stands. In intense fires such as those used in this study, it appeared that most down woody material was consumed in the fire. In harvest stands, there was considerable woody debris left at the site. Although coarse DWM was greater in the 1993 harvest stands relative to the 1993 burn stands, these levels of coarse DWM should be maintained in order that the volume converges with burn stands in the 1980 disturbance age-class.

The average diameter of coarse DWM was almost 1.5 times greater in the 1993 harvest stands than the burn stands. In order to have convergence of coarse DWM volume at 16 years post-harvest, the diameter of coarse DWM as found in the 1993 harvest stands should be adopted as the template for maintaining future coarse DWM. The distribution of coarse DWM in diameter categories was similar between disturbance types.

In harvested stands, the stage of decay shifted from lower to higher decay stages as time from disturbance increased while the distribution of decay remained relatively constant in the burn stands. The coarse DWM in 1993 harvest stands tended to be stripped of bark and in small pieces. Although it was found that small pieces of debarked wood in clearcuts decay more quickly than larger intact pieces (Arthur *et. al.* 1993), it has also been found that the presence of bark results in retention of water, and thus, more rapid decay (Erickson *et. al.* 1985). In this study, the higher stages of decay in burn stands could be the result of a single input event being responsible for most coarse DWM in harvest stands. In burn stands, DWM inputs would come mainly from large diameter burned snags contributing to DWM at random. This would keep the decay distribution of logs relatively constant in the burn stands. Although difficult to mimic the input of snags to coarse DWM when few snags are present, it may be possible to increase the size of woody debris left at the harvest site perhaps slowing the rate of decay.

The following guidelines are recommended for maintaining coarse DWM in accordance with a natural disturbance approach to forest management:

- ◆ to obtain convergence in volume at a stand level, density, diameter, and length of coarse DWM 1993 harvest stands must be approximated. At the stand level, density of coarse DWM should equal 0.04 ± 0.005 pieces/7m with a range of 0.03 to 0.05. Average diameter should be 20.0 ± 1.2 cm at the time of harvest. The distribution of coarse DWM should fall in the following diameter categories:
 - 37 to 57% in 10.0 to 14.9cm DBH
 - 14 to 21% in 15.0 to 19.9cm DBH
 - 0 to 15% in 20.0 to 24.9cm DBH
 - 0 to 11% in 25.0 to 29.9cm DBH
 - 0 to 4% in 30.0 to 34.9cm DBH
 - 0 to 21% in 35.0 to 39.9cm DBH
 - 0 to 2% in 40.0 to 44.9cm DBH
 - 2 to 7% in 45.0 to 49.9cm DBH
 - 0% in 50.0 to 54.9cm DBH
 - 0 to 7% in 55.0 to 59.9cm DBH
 - 0 to 7% in 60.0 to 64.9cm DBH

Average length of coarse DWM at the stand level should be 9.3 ± 0.9 m with a range of 6.5 to 10.5m at the time of harvest. The distribution of coarse DWM should fall in the following length categories:

- 7 to 71% in 0.0 to 4.9m
 - 0 to 39% in 5.0 to 9.9cm DBH
 - 10 to 15% in 10.0 to 14.9cm DBH
 - 0 to 8% in 15.0 to 19.9cm DBH
 - 0 to 14% in 20.0 to 24.9cm DBH
- ◆ at the stand level, average coarse DWM diameter should be 17.9 ± 1.8 cm DBH. The distribution of snags should fall within the following diameter categories with a range of 10.0 to 56.0cm DBH:
 - 23 to 70% in 10.0 to 14.9cm DBH
 - 20 to 34% in 15.0 to 19.9cm DBH
 - 6 to 17% in 20.0 to 24.9cm DBH
 - 3 to 12% in 25.0 to 29.9cm DBH
 - 0 to 13% in 30.0 to 34.9cm DBH

- 0 to 5% in 35.0 to 39.9cm DBH
- 0 to 3% in 40.0 to 44.9cm DBH
- 0 to 4% in 45.0 to 49.9cm DBH
- 0 to 1% in 50.0 to 54.9cm DBH
- 0 to 1% in 55.0 to 59.9cm DBH

Seedlings

Other than large diameter snags, seedling abundance had the greatest difference in abundance of forest attributes in burn stands relative to harvest stands in both the 1993 and 1980 disturbance age-classes. Convergence did occur in the 1969 disturbance age-class. To match seedling abundance found in burn stands, harvest sites would have to be planted with twenty times the seedlings that are planted at present.

Although seemingly unimportant in future tree densities, seedling density could have the potential to affect many of the forest attributes that would be virtually impossible to directly manipulate in harvest stands. The presence of seedlings, and resulting saplings and small diameter trees and snags, at levels found in burn stands could change the dynamics of herbs and the tall, mid, and low shrub communities as well as medium DWM inputs, ground cover types, and canopy cover attributes. All these forest attributes differed significantly between treatment types in at least one disturbance age-class.

Increasing seedling density would likely be counter-productive to the objective of replanting; to replace merchantable timber in the quickest time at the lowest cost. However, since replanting occurs anyways, it might be a relatively inexpensive way to more closely mimic fire disturbed stands. It is an untested theory that changing seedling densities would result in this cascading change in other forest attributes. It may result only in increasing seedling densities, but this in itself would be one step closer to mimicking fire disturbed sites.

The following guidelines are recommended for maintaining seedling abundance in accordance with a natural disturbance approach to forest management:

- ◆ at the stand level, average seedling frequency should be $1,128 \pm 372.5$ seedlings/per 36mx36m harvested area with a range of 481 to 2,188 seedlings.
- ◆ seedling species should be within the following distribution; 15 to 80% white spruce, 5 to 18% lodge pole pine, 0 to 20% trembling aspen, 0 to 1% paper birch, 16 to 66% balsam poplar, and 0 to 18% black spruce.

4. Relative Abundance and Species Richness of Small Mammals and Birds in Three Age-Classes of Burn and Harvest Stands in White Spruce-Dominated Forest

4.1 Introduction

Changes in forest community structure and composition are important issues in the pursuit of biological conservation. As timber harvesting replaces fires as the dominant disturbance regime in the boreal forest, there is increasing concern for the effect this shift in disturbance regime has on community structure and composition.

To reduce potential changes in biodiversity arising from timber harvesting, it has been proposed that forest companies use harvest techniques that mimic natural disturbance processes (Titterington *et al.* 1979; DesGranges and Rondeau 1992; Hunter 1993, Thompson 1992). Both fires and timber harvest alter stand structure and composition (DesGranges & Rondeau 1992), but it is not known whether structural and compositional differences exist between these two disturbance regimes and, if extant, how they may affect wildlife.

In past studies, effects of harvesting and fires on species diversity and abundance have been compared to undisturbed forests. Not surprisingly, vast differences in vegetation and wildlife diversity were found between disturbed and undisturbed forests.

Studies investigating the effects of clearcut harvesting on wildlife communities found that after harvesting, the number and species richness of birds increased over time and often increased to levels higher than in mature forests (Kavanagh *et al.* 1985; DesGranges & Rondeau 1992). In a study on small mammals, Kirkland (1977) found that in coniferous forests, clearcut harvesting initially resulted in an increase in abundance, diversity, and density of small mammals, followed by a decrease with succession. Although Ramirez and Hornocker (1981) stated that timber harvesting may simulate fires by providing a variety of habitats for small mammals as succession occurs, their failure to actually compare harvest and burn stands renders this conclusion speculative.

Fox (1983) reviewed a number of papers on post-fire succession of wildlife communities for North American boreal forests. Under this disturbance regime, he also found an increasing trend in bird species diversity and richness with succession to a mature forest stage. Numbers of birds increased to the shrub stage to levels higher than mature forests, but were lower in the sapling

stages. After fire disturbance, small mammal abundance was greatest in the early stages of succession relative to mature forest, but was lower in the shrub and sapling stages.

Thus, based on previous, although separate, investigations, there appear to be some similarities in the patterns of abundance and diversity of birds and small mammals in harvest and fire disturbed stands. This information lends promise to the possibility that diversity of harvested forests can be maintained under a natural disturbance approach to forest management.

To test this, the present study incorporated comparisons of bird and small mammal abundance and richness between comparable burned and logged stands, with burn stands the template for natural disturbance. Furthermore, a comparison of species diversity between fire and harvest stands in three disturbance age-classes, 3, 16, and 24 years post disturbance, allowed us to determine whether the integrity of the forest had been affected by harvest practices, and if so, does this integrity recover with time.

The following objectives were met:

- 1) Determine if there are any differences in species richness and abundance between treatment types, and if so, do differences decrease with time since disturbance.
- 2) Identify forest structures highly correlated with any species whose abundance was affected by treatment type.
- 3) Make harvest management recommendations based on results.

4.2 Methods

4.2.1 Small Mammal Trapping

Live trapping sessions were conducted in each of two years; 1997 and 1998. Each stand was pre-baited for three consecutive nights followed by three consecutive trap nights. Longworth traps were located at 40m intervals, 40m apart on either side along a 500m permanent transect. To keep trap location constant and avoid edge effects, traps were located a minimum of 100m from the harvest or burn edge. Species and sex were recorded for all captured animals. Due to the large spatial scale of this study, only eight stands could be trapped simultaneously. To reduce the amount of time between trapping sessions, three days of trapping for eight stands was overlapped with the pre-baiting of another eight stands.

In 1997, pre-baiting began on May 8 in the 1980 and 1969 harvest stands, on May 11 for the 1969 burn and 1993 harvest stands, and on May 15 for the 1993 burn stands. Due to a late snowfall and extremely wet conditions, the 1980 burn stands were inaccessible at this

time. As a result, the 1980 harvest stands were retrapped at the same time that access was gained to the 1980 burn stands on June 6. In each stand, a total of 16 traps were pre-baited for three nights followed by three consecutive trap nights.

In 1998, pre-baiting began on May 6 in the 1969 and 1980 harvest stands and May 10 in the 1969 burn and 1993 harvest stands. On May 20, pre-baiting began in the 1980 and 1993 burn stands. As in 1997, each stand was pre-baited for three nights followed by three consecutive trap nights. To increase trapping effort, the number of traps was increased to 22 traps per stand in 1998.

4.2.2 Avian Census

Point count sampling for breeding birds occurred in each of two years, 1997 and 1998 between the last week of May until early July. Two point count stations were located 250m apart at the end of a permanent transect for each harvest and burn stand. Point count stations were located 125m from the harvest or burn edge to reduce edge effects (Hansson 1983).

Observers were trained prior to conducting surveys and each site was sampled by a different observer for each visit. Bird censuses began at sunrise and continued until no later than 10:00 a.m. After arriving at the site, observers waited for two minutes, then recorded bird calls for a period of five minutes. Species seen and heard within and outside a 50m radius were recorded separately. Individual birds were recorded once by noting the location and movements of birds. After each survey, observers attempted to visually identify bird vocalizations that could not be recognized. To further aid identification of unknown bird vocalizations, all surveys were recorded using a unidirectional microphone and compared to tapes of identified bird vocalizations.

Surveys were not conducted in windy or rainy conditions due to reduced detectability of vocalizations (Ralph *et al.* 1992). Because vocalization rates can vary throughout the morning (Skirvin 1981), the sequence that stands were sampled were systematically varied. Birds that flew over the sampling sites without landing were recorded, but they were not used in the analysis.

Although it is difficult to hear birds beyond 125m in a forested habitat (Hansson 1983), it was evident that this distance was exceeded in the 1993 harvest stands where there was virtually no vegetation or structure. For this reason, vocalizations that were detected, but

determined to be coming from the forest (further than 125m), were not included in the analysis. This helped to reduce some of the bias of this sampling technique when compared across different forest types.

4.2.3 Data Analysis

For analysis of bird and small mammal abundance data, blocked analysis of variance was used with one among-subjects factor and one within subjects-factor (Zar 1996). Individual stands (N=4) were nested within burn and harvest treatment types for the among-subjects factor. Individual species abundance was used as the within-subjects factor. Effects of treatment on total abundance were determined using the main effect term between subjects. Effects of treatment on relative abundance of species was determined using the within subjects interaction term. To interpret these data, a significance level of 0.10 was used as it has been suggested that Type II errors in applied research can be more costly than Type I errors (Schmiegelow *et. al.* 1997). To test for differences in individual species abundance, a Mann Whitney test with tied ranks was used.

Canonical discriminant function analysis was used to describe the association of vegetation characteristics with both small mammal and bird species abundance. Only 1997 abundance data were used as this was the year that the majority of the vegetation variables were measured. Wilks' Lambda was used to test for significance between abundance categories at a 10% probability level. The structural coefficients were used to determine how vegetation variables contributed to the separation observed among abundance centroids. The original vegetation data set included 29 variables. A subset of variables for use in analysis was chosen based on three criteria; variables that realistically could be manipulated by harvest companies at the time of harvest, variables that would likely have some importance to the species in terms of cover, forage, or nesting material, and variables that were not correlated to other variables used in the analysis.

4.3 Results

4.3.1 Small Mammal Trapping

Comparison of Small Mammal Diversity Between Disturbance Types in Three Age-classes Year 1

In 1997, a total of 215 small mammals were captured in 1,152 trap nights. In all treatment types, red-backed voles were the most abundant species followed by deer mice.

Capture rates in the 1993 disturbed stands were more than twice as great in harvested (18.5 ± 4.6) versus burn stands (9.0 ± 1.5 ; blocked ANOVA; $F=3.910$, $df=1$, $p=0.095$; Figure 4.1a). The meadow vole was found only in harvest stands in addition to the red-backed vole and deer mouse that were found in both treatment types with significantly greater species richness in harvest stands (2.5 ± 0.3) than burn stands (1.3 ± 0.3 ; Mann Whitney test; $U_{0.10(2),4,4}=0.032$). The relative abundance of small mammal species did not differ significantly between treatment types ($F=0.429$, $df=2$, $p=0.661$).

The difference in total abundance between treatments in the 1980 age-class was insignificant ($F=0.192$, $df=1$, $p=0.677$) largely due to a sharp decrease in small mammal abundance in the harvest stands (7.5 ± 2.6) while abundance dropped only slightly in the 1980 burn stands (6.3 ± 1.1 ; Figure 4.1b). In addition to the red-backed vole and deer mouse found in both treatment types, the meadow vole was found exclusively in burn stands and the jumping mouse and chipmunk were found exclusively in harvest stands. Species richness was similar between burn (1.5 ± 0.3) and harvest stands (1.3 ± 0.5 ; Mann Whitney test; $U_{0.10(2),4,4}=0.752$) and relative abundance of species did not differ between treatment types ($F=0.906$, $df=2$, $p=0.476$).

In the 1969 age-class, total abundance of small mammals continued to drop in the harvest stands (5.0 ± 2.6) to levels below abundance in burn stands (7.5 ± 4.6), but the difference between the two treatments types remained insignificant ($F=0.216$, $df=1$, $p=0.658$; Figure 4.1c). In addition to the red-backed vole and deer mouse found in both treatment types, the meadow vole was found in harvest stands with no difference in relative abundance ($F=0.450$, $df=2$, $p=0.648$) or species richness (1.3 ± 0.5 in burns and 1.3 ± 0.6 in harvests; Mann Whitney test; $U_{0.10(2),4,4}=0.617$) between treatment types.

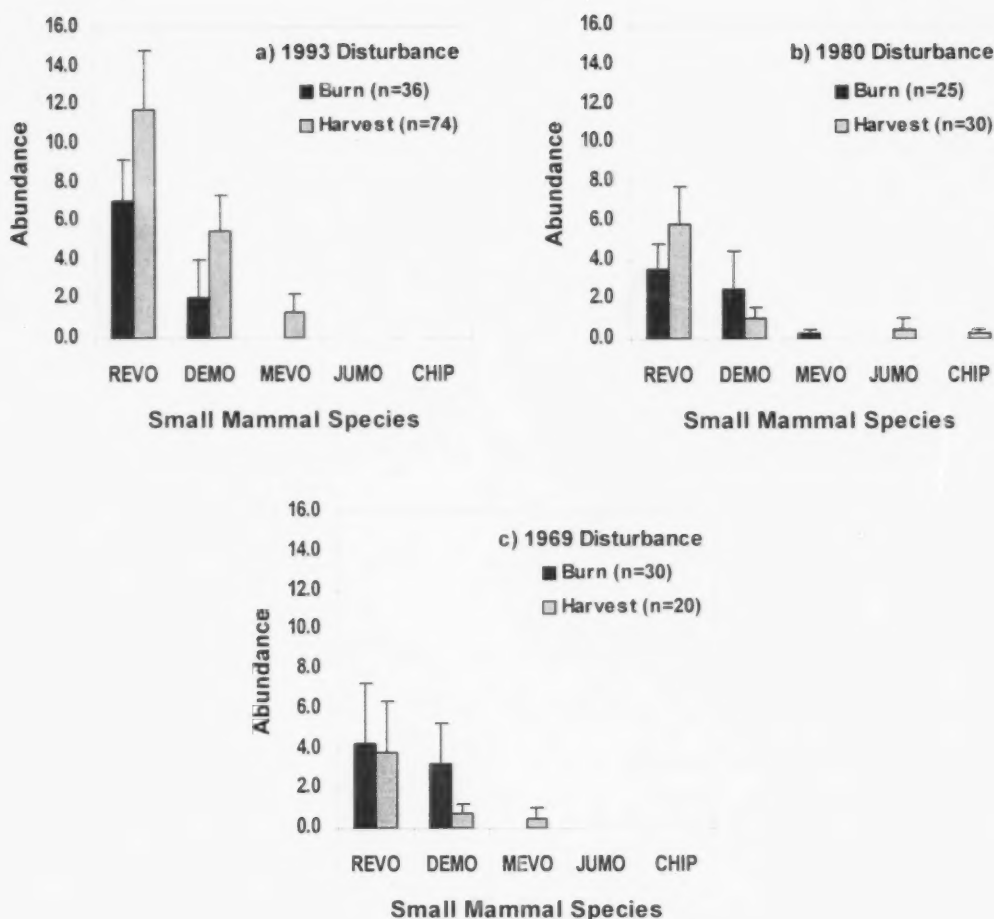


Figure 4.1. The average abundance of small mammals for Year 1 of study in burn (N=4) and harvest (N=4) stands in three age-classes a) 1993, b) 1980, and c) 1969 of white spruce dominated stands. REVO=red-backed vole, DEMO=deer mouse, MEVO=meadow vole, JUMO=jumping mouse, CHIP=chipmunk.

Abundance of Small Mammals in Relation to Vegetation Characteristics

Significant canonical discriminant functions occurred for both red-back voles and deer mice (Table 4.1), although function 2 was not significant for the red-backed vole. Analysis was not done on meadow voles, jumping mice, and chipmunks because abundance was very low (<3 captures in any one treatment) for these species. The power of this test is low for species with low abundance (Schieck *et. al.* 1995).

For the red-backed vole, coarse DWM and percent cover of moss were the most important variables for distinguishing between abundance categories (Table 4.1; Wilks' Lambda $\chi^2=$, $df=6,38$, $p=0.053$; Figure 4.2a). Very low and very high densities of coarse DWM and very low and very high percent moss cover accounted for high abundance of red-backed voles.

Large diameter trees and percent ground cover were the two variables that accounted for the separation observed between abundance groups for the deer mouse (function 1 $\chi^2=$, $df=8,36$, $p=0.003$; function 2 $\chi^2=$, $df=3,20$, $p=0.003$; Table 4.1). Absence of deer mice occurred at both high densities of large diameter trees and low percent canopy cover from ground level was correlated to low abundance of deer mice (Figure 4.2b).

Table 4.1. Structural coefficients from the correlation between forest attributes and the canonical discriminant functions used to separate abundance categories for each small mammal species in white spruce-dominated stands in Alberta.

	Red-backed Vole		Deer Mouse	
	Function 1	Function 2	Function 1	Function 2
DWM Density (≥ 10 cm dbh)	0.659	0.752	-0.296	0.001
Moss Cover %	0.515	-0.005	0.241	-0.003
Tree Density (≥ 10 cm dbh)	0.310	-0.049	0.430	-0.860
DWM Frequency (< 10 cm dbh)	0.016	0.163	-0.307	0.047
Canopy Cover	-0.065	-0.185	0.414	-0.177
Shrub Frequency (> 3 m ht)	-0.112	0.211	0.393	0.255
DWM Frequency (< 5 cm dbh)	-0.125	0.002	-0.356	0.108
Shrub Frequency (> 1 m ht)	-0.269	-0.209	0.266	0.119
Shrub Cover (< 1 m ht; %)	-0.361	0.215	-0.193	0.001
Snag Density (≥ 10 cm dbh)	-0.445	-0.338	0.135	0.305
Herb Cover (%)	-0.485	0.874	-0.277	-0.050
Wilks' Lambda	0.54	0.85	0.30	0.64
df	6,38	2,21	8,36	3,20
P	0.053	0.207	0.003	0.032
Proportion Explained	0.37	0.15	0.85	0.36

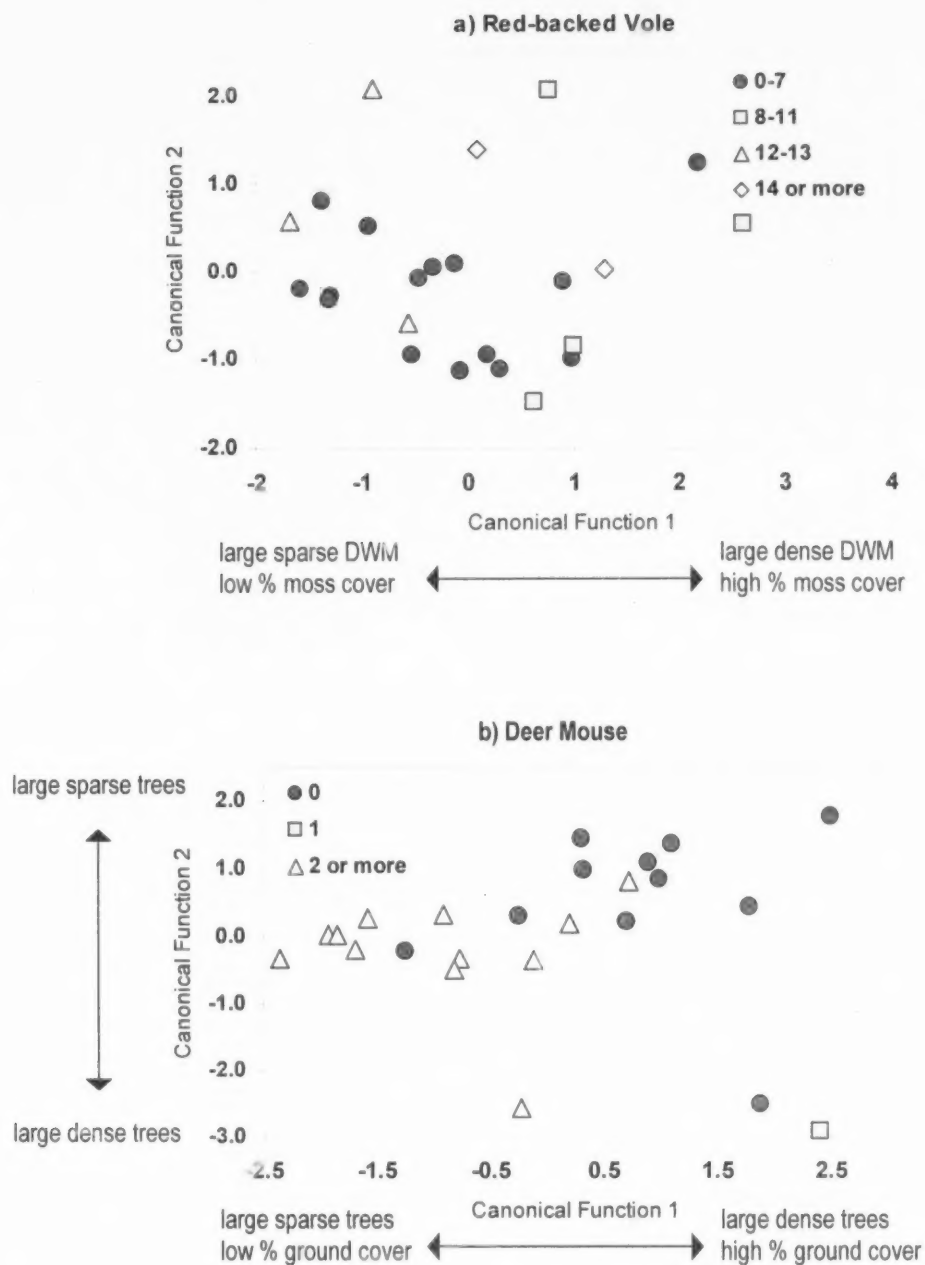


Figure 4.2. The separation observed between abundance categories for a) red-backed vole and b) deer mouse across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant scores.

Year 2

In 1998, a total of 383 small mammals were captured in 1,584 trap nights. As with the year 1 data, red-backed voles were the most abundant species followed by deer mice in all treatment types.

In the 1993 age-class, total abundance was slightly greater in harvest stands (19.0 ± 5.1) than burn stands (16.0 ± 3.6), but the difference was not significant (blocked ANOVA; $F=0.227$, $df=1$, $p=0.651$; Figure 4.3a). The meadow vole was found exclusively in harvest stands in addition to the red-backed vole and deer mouse that were found in both treatment types. Species richness was very similar in burn (2.0 ± 0.0) and harvest stands (2.3 ± 0.5 ; Mann Whitney test; $U_{0.10(2),4,4}=0.505$) and relative abundance of small mammals did not differ between treatment types ($F=1.079$, $df=2$, $p=0.371$).

Total abundance dropped slightly in the 1980 age-class. Although the decrease in abundance was greater in harvest stands (11.5 ± 1.7) than burn stands (14.3 ± 2.6), the difference between treatment types remained insignificant ($F=0.771$, $df=1$, $p=0.414$; Figure 4.3b). As in year 1 of study, chipmunks and jumping mice were present only in the 1980 age-classes. A total of four species were found in both burn and harvest stands (2.3 ± 0.8 and 2.0 ± 0.4 , respectively; $U_{0.10(2),4,4}=0.881$). In addition to the red-backed vole, deer mouse and meadow vole, the jumping mouse was found exclusively in harvest stands whereas chipmunks were found only in burn stands. Relative abundance did not differ between burn and harvest stands ($F=0.486$, $df=4$, $p=0.740$).

Total abundance rose again in the 1969 age-class, but the difference between burn (19.5 ± 3.4) and harvest (15.5 ± 3.1) stands remained insignificant ($F=0.762$, $df=1$, $p=0.416$; Figure 4.3c). The red-backed vole, deer mouse, and meadow vole were found in both burn and harvest stands with no measurable difference between treatment types in relative abundance ($F=0.421$, $df=2$, $p=0.666$) or species richness stands (2.0 ± 0.4 in burns and 1.8 ± 0.3 in harvests; $U_{0.10(2),4,4}=0.881$).

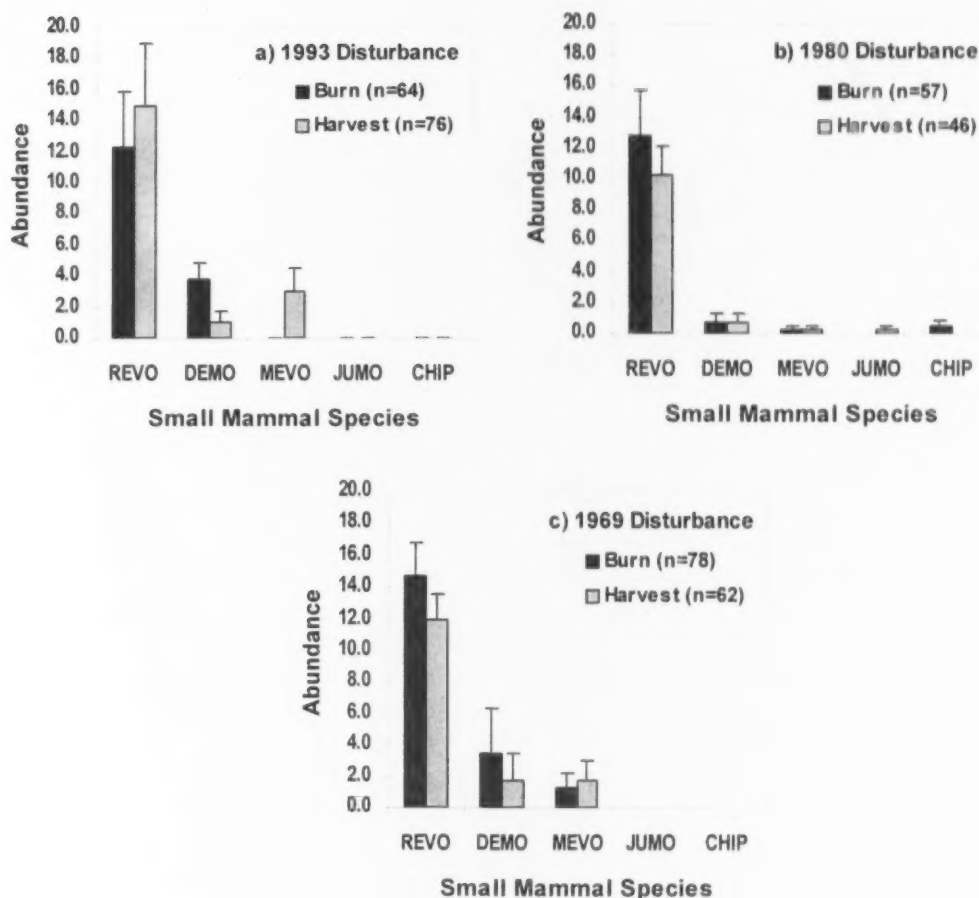


Figure 4.3. The average abundance of small mammal species for year 2 of study in burn (N=4) and harvest (N=4) treatments in a) 1993, b) 1980, and c) 1969 disturbance age-classes of white spruce-dominated stands. REVO=red-backed vole, DEMO=deer mouse, MEVO=meadow vole, JUMO=jumping mouse, CHIP=chipmunk.

4.3.2 Avian Census

Comparison of Bird Diversity Between Disturbance Types

Year 1

In the 1993 age-class, total abundance of all species was similar between burn (53.3 ± 2.2) and harvest stands (49.3 ± 7.6 ; blocked ANOVA; $F=0.345$, $df=1$, $p=0.578$). However, the relative abundance of individual species was not the same between treatments ($F=6.520$, $df=28$, $p<0.000$) with abundance of eight species differing between the two treatment types, five of which had a greater abundance in burn stands (Mann Whitney test

with tied ranks; $U_{0.10,4,4}$; Table 4.2). No difference in species richness was found between treatment types (15.5 ± 1.3 in burns and 17.8 ± 1.3 in harvest stands; $U_{0.10,4,4} = 0.306$).

The number of species detected in the 1980 age-class increased slightly over the 1993 age-class, but differences in the number of species recorded in burn stands (21.0 ± 1.3) versus harvest stands (20.0 ± 1.7) remained insignificant ($U_{0.10,4,4} = 0.772$). Although total abundance of species increased in the 1980 age-class, there was no significant difference between treatments (64.0 ± 8.8 in burns and 73.0 ± 7.2 in harvest stands; $F = 0.626$, $df = 1$, $p = 0.459$). As in the 1993 age-class, abundance of individual species differed between burns and harvests ($F = 2.756$, $df = 31$, $p < 0.000$) with four species having a greater abundance in burn stands and three species with a greater abundance in harvest stands (Table 4.2).

In the 1969 age-class as with the 1993 and 1980 age-class, no difference was found in species richness (16.8 ± 2.5 in burns and 18.8 ± 3.0 in harvest stands; $U_{0.10,4,4} = 0.663$) or total abundance of species (65.5 ± 5.2 in burns and 58.0 ± 4.1 in harvest stands; $F = 1.490$, $df = 1$, $p = 0.268$). Similarly, the effect of treatment was significant ($F = 2.267$, $df = 29$, $p = 0.001$) on individual species abundance with white-throated sparrows in greater abundance in burn stands and white-winged crossbills more abundant in harvest stands (Table 4.2).

Table 4.2. Total abundance of bird species in burn and harvest stands in each age-class for Year 1 of study. N=4 for each treatment type. All *P* values are based on Mann-Whitney tests. NS=not significant, - = not tested.

Species	Year 1								
	1993			1980			1969		
	Burn	Harvest	p-value	Burn	Harvest	p-value	Burn	Harvest	p-value
White-throated Sparrow	75	26	0.028	41	51	NS	52	9	0.021
Tennessee Warbler	2	11	0.036	27	28	NS	40	22	NS
Swainson's Thrush	9	5	NS	15	21	NS	23	28	NS
Magnolia Warbler	0	12	0.013	3	4	NS	22	25	NS
Chipping Sparrow	19	9	NS	12	11	NS	20	15	NS
Dark-eyed Junco	13	18	NS	9	4	NS	15	14	NS
Least Flycatcher	9	1	0.034	7	0	0.046	9	5	NS
Warbling Vireo	1	3	NS	4	16	NS	8	6	NS
Yellow-rumped Warbler	7	5	NS	15	3	0.099	7	17	NS
Orange-crowned Warbler	2	3	NS	14	7	NS	7	7	NS
Alder Flycatcher	0	20	0.014	19	24	NS	6	11	NS
Fox Sparrow	0	0	-	0	1	-	6	0	NS
Ovenbird	0	0	-	1	3	NS	6	0	NS
Wilson's Warbler	2	0	-	4	1	NS	4	3	NS
American Redstart	4	4	NS	5	4	NS	4	2	NS
Northern Flicker	9	1	0.025	5	2	NS	3	6	NS
Ruffed Grouse	3	0	NS	3	4	NS	3	3	NS
Red-eyed Vireo	1	2	-	0	35	0.013	3	2	NS
Black and White Warbler	0	1	-	3	13	0.017	3	0	NS
Hermit Thrush	2	0	-	11	1	0.025	3	0	NS
Gray Jay	2	8	NS	5	11	NS	2	6	NS
Brown Creeper	7	8	NS	3	1	NS	2	3	NS
Solitary Vireo	0	3	NS	1	4	NS	2	2	-
Black-capped Chickadee	0	1	-	2	0	-	2	1	-
Mourning Warbler	0	1	-	3	2	NS	2	0	-
Winter Wren	0	3	NS	5	4	NS	1	7	NS
Ruby-crowned Kinglet	0	4	NS	0	2	-	1	6	NS
Yellow Warbler	4	0	NS	2	4	NS	1	6	NS
American Robin	4	4	NS	1	4	NS	1	4	NS
Rose-breasted Grosbeak	0	1	-	1	11	0.034	1	3	NS
Red-breasted Nuthatch	1	1	-	1	1	-	1	3	NS
Olive-sided Flycatcher	3	2	NS	2	2	-	1	1	-
Song Sparrow	2	21	0.019	9	6	NS	1	1	-
White-winged Crossbill	0	0	-	0	0	NS	0	6	0.046
House Wren	6	7	NS	5	2	NS	0	4	NS
Common Yellowthroat	5	0	0.046	10	3	NS	0	2	-
Lincoln's Sparrow	0	6	NS	3	0	NS	0	1	-
Yellow-bellied Sapsucker	3	1	NS	1	1	-	0	1	-
Common Redpoll	0	3	NS	1	1	-	0	0	-
Connecticut Warbler	0	2	-	3	0	0.040	0	0	-
Western Wood Peewee	18	0	0.046	0	0	-	0	0	-

Note: only species with 3 or more detections in at least one treatment type were included in analysis.

Year 2

In the 1993 age-class, a total of 303 birds were sampled in burn stands as compared to 190 in harvest stands. White-throated sparrow was the most abundant species in the burns and alder flycatcher was most abundant in the harvest stands. Average total abundance was 1.5 times greater in burn stands (75.8 ± 6.4) than harvest stands (47.5 ± 3.6 ; blocked ANOVA; $F=14.97$, $df=1$, $p=0.008$). Species richness was greater in burn stands (20.0 ± 1.4) than harvest stands (14.3 ± 1.8 ; $U_{0.10,4,4}=0.058$). The effect of treatment on relative abundance was significant ($F=10.525$, $df=23$, $p<0.000$) with seven species more abundant in burn stands and two species more abundant in harvest stands (Mann Whitney test with tied ranks; $U_{0.10,4,4}$; Table 4.3).

A total of 320 and 340 birds were sampled in the 1980 burn and harvest stands, respectively. Average total abundance of species increased in the 1980 harvest stands (86.8 ± 8.4) to converge with the abundance of species in the burn stands (80.0 ± 9.2 ; $F=0.0217$, $df=1$, $p=0.657$). The effect of treatment on relative abundance was not significant ($F=1.135$, $df=29$, $p=0.302$). Species richness did not differ significantly between burn stands (18.5 ± 1.2) and harvest stands (20.0 ± 1.4 ; $U_{0.10,4,4}=0.058$).

In the 1969 age-class, a total of 371 and 279 birds were recorded in burn and harvest stands, respectively. Total abundance of species diverged between treatments in the 1969 age-class as it continued to increase in burn stands (92.8 ± 5.0) and decreased in harvest stands (69.8 ± 8.6) from the 1980 levels. ($F=5.355$, $df=1$, $p=0.060$). The effect of treatment was significant on species composition ($F=3.554$, $df=22$, $p<0.000$) with abundance of six species greater in the burns and one species abundance greater in the harvest stands (Table 4.3). Species richness also differed between treatment types with a greater number of species in burn stands (18.0 ± 0.9) than harvest stands (15.0 ± 1.1 ; $U_{0.10,4,4}=0.083$).

Table 4.3. Total abundance of bird species in burn and harvest stands in each age-class for Year 2 of study. N=4 for each treatment type. All *P* values are based on Mann-Whitney tests. NS=not significant, - = not tested.

Species	Year 2								
	1993			1980			1969		
	Burn	Harvest	p-value	Burn	Harvest	p-value	Burn	Harvest	p-value
White-throated Sparrow	90	28	0.020	78	67	NS	72	12	0.020
Swainson's Thrush	18	4	0.041	29	36	NS	58	59	NS
Tennessee Warbler	15	6	NS	38	45	NS	38	38	NS
Chipping Sparrow	10	23	0.041	16	11	NS	26	26	NS
Fox Sparrow	0	0	-	0	1	-	21	1	0.091
Hermit Thrush	18	0	0.014	19	9	NS	20	10	0.080
Magnolia Warbler	3	6	NS	8	17	NS	19	33	NS
Alder Flycatcher	15	42	0.020	29	42	NS	18	4	NS
Orange-crowned Warbler	3	2	NS	13	3	0.078	16	0	0.047
Red-breasted Nuthatch	1	5	NS	7	4	NS	13	14	NS
Least Flycatcher	7	0	NS	11	1	0.025	13	1	0.091
Gray Jay	24	5	NS	11	7	NS	8	19	NS
Wilson's Warbler	7	6	NS	1	3	NS	7	2	0.063
Yellow-rumped Warbler	2	8	NS	1	4	NS	6	10	NS
Warbling Vireo	0	0	-	5	7	NS	6	4	NS
Ovenbird	0	0	-	0	1	-	6	1	NS
Dark-eyed Junco	7	13	NS	8	4	NS	5	22	0.038
Red-eyed Vireo	2	2	-	2	30	NS	5	1	NS
Northern Flicker	17	0	0.013	5	2	NS	4	1	NS
Black and White Warbler	2	0	-	10	11	NS	3	0	NS
Brown Creeper	7	2	0.099	4	2	NS	2	4	NS
Winter Wren	5	5	NS	8	4	NS	1	4	NS
American Redstart	1	0	-	1	5	0.040	1	2	-
Common Yellowthroat	2	0	-	0	3	0.040	1	2	-
Rose-breasted Grosbeak	3	1	NS	2	7	NS	1	2	-
Olive-sided Flycatcher	11	1	0.026	0	2	-	1	0	-
Ruffed Grouse	1	0	-	2	6	NS	0	3	NS
Canada Warbler	0	0	-	2	3	NS	0	1	-
Mourning Warbler	3	7	NS	5	0	NS	0	1	-
Western Wood Peewee	10	0	0.047	0	4	NS	0	1	-
Yellow Warbler	1	0	-	0	3	NS	0	1	-
Clay-colored Sparrow	2	7	NS	0	0	-	0	0	-
Connecticut Warbler	9	2	NS	2	3	NS	0	0	-
Song Sparrow	7	15	NS	3	0	NS	0	0	-

Note: only species with 3 or more detections in at least one treatment type were included in analysis.

Species Abundance in Relation to Vegetation Attributes

To determine if specific vegetation attributes were important in determining bird abundance, regardless of treatment type, vegetation characteristics were compared to abundance for each species across all 24 stands using canonical discriminant function analysis. Because analyses would be complicated by the large number of vegetation variables sampled, a smaller subset was used for this analyses. The subset chosen was based on the following criteria; variables that were not highly correlated with others based on the Pearson Correlation Coefficient, variables that could be manipulated at the harvest site such as density of large diameter snags, DWM, and live trees as well as seedlings and were likely to be important vegetation characteristics for birds based on cover, foraging, and nesting needs.

Results from the canonical discriminant analyses can be interpreted from Table 4.4 and Figures 4.4a to oo). Only species with a significant correlation were listed in the tables and figures. For example, canonical discriminant function analysis for the American robin (Figure 4.4b, Table 4.4) produced a single function that resulted in significant separation between abundance categories (Wilks' Lambda; $\chi^2=0.740$, $df=2,21$, $p=0.043$, $R^2=0.26$). Snag (≥ 10 cm DBH) density was most highly correlated with the function followed by coarse DWM that was negatively correlated with the function.

Table 4.4. Structural coefficients from the correlation between forest attributes and the canonical discriminant functions used to separate abundance categories for each bird species in white spruce-dominated stands in Alberta.

	Alder Flycatcher		American Robin	Black and White Warbler	Black-capped Chickadee	Black-throated Green Warbler
	Function 1	Function 2	Function 1	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	-0.28	0.86	0.62	0.30	-0.46	-0.14
Tree Density (≥ 10 cm dbh)	-0.27	-0.40	-0.19	0.06	-0.16	-0.17
DWM Density (≥ 10 cm dbh)	0.11	-0.56	-0.38	-0.10	0.34	0.32
DWM Frequency (< 10 cm dbh)	-0.10	0.06	0.07	0.37	0.71	0.10
DWM Frequency (< 5 cm dbh)	0.77	0.34	-0.27	-0.20	0.14	0.80
Shrub Frequency (≥ 3 m ht)	0.25	-0.46	-0.27	-0.33	0.13	0.10
Shrub Frequency (≥ 1 m ht)	-0.03	-0.14	-0.28	-0.59	-0.15	0.11
Snag Frequency (< 10 cm dbh)	0.15	0.44	-0.25	0.12	-0.24	0.09
Herb Cover (%)	0.29	0.10	-0.18	0.00	0.13	0.12
Wilks' Lambda	0.25	0.74	0.74	0.36	0.76	0.40
df	6,38	2,21	2,21	4,19	2,21	3,20
P	<0.000	0.051	0.043	<0.001	0.056	<0.001
Proportion Explained	0.67	0.26	0.26	0.64	0.24	0.60

Table 4.4 (continued).

	Brown Creepers	Clay-colored Sparrow	Chipping Sparrow	Connecticut Warbler	Common Yellowthroat	Dark-eyed Junco
	Function 1	Function 1	Function 1	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	-0.24	0.36	-0.15	0.12	-0.36	-0.05
Tree Density (≥ 10 cm dbh)	-0.16	-0.13	-0.32	-0.14	0.08	-0.17
DWM Density (≥ 10 cm dbh)	0.08	-0.18	0.12	0.18	0.77	0.39
DWM Frequency (< 10 cm dbh)	-0.11	0.12	0.23	0.40	0.46	-0.08
DWM Frequency (< 5 cm dbh)	0.13	-0.21	0.35	-0.25	-0.10	-0.06
Shrub Frequency (≥ 3 m ht)	1.00	-0.18	-0.12	0.38	0.10	0.29
Shrub Frequency (≥ 1 m ht)	0.36	0.09	-0.29	0.67	0.14	1.00
Snag Frequency (< 10 cm dbh)	-0.09	0.68	-0.16	0.22	-0.08	0.09
Herb Cover (%)	-0.01	-0.64	0.33	-0.05	0.05	-0.22
Wilks' Lambda	0.63	0.78	0.23	0.69	0.72	0.70
df	1,22	2,21	5,18	2,21	2,21	2,21
P	0.002	0.069	<0.001	0.019	0.030	0.015
Proportion Explained	0.37	0.23	0.77	0.28	0.28	0.33

Table 4.4 (continued).

	Fox Sparrow	Gray Jay	Hermit Thrush	Least Flycatcher	Magnolia Warbler	
	Function 1	Function 1	Function 1	Function 1	Function 1	Function 2
Snag Density (≥ 10 cm dbh)	-0.08	1.00	0.21	0.59	0.76	-0.65
Tree Density (≥ 10 cm dbh)	0.00	-0.39	-0.02	0.20	0.01	0.29
DWM Density (≥ 10 cm dbh)	-0.15	-0.60	-0.02	-0.27	-0.11	0.99
DWM Frequency (< 10 cm dbh)	-0.08	0.13	-0.21	0.36	0.11	-0.05
DWM Frequency (< 5 cm dbh)	-0.04	-0.15	-0.02	-0.34	-0.26	0.13
Shrub Frequency (≥ 3 m ht)	0.70	-0.19	0.17	-0.24	-0.22	0.05
Shrub Frequency (≥ 1 m ht)	-0.01	0.03	0.67	-0.26	-0.03	0.30
Snag Frequency (< 10 cm dbh)	0.02	0.43	0.74	0.21	0.10	-0.25
Herb Cover (%)	0.24	0.03	0.07	-0.02	-0.05	-0.11
Wilks' Lambda	0.45	0.81	0.72	0.64	0.39	0.98
df	3,20	1,22	2,21	3,20	4,40	1,22
P	0.001	0.035	0.032	0.099	0.001	0.500
Proportion Explained	0.55	0.19	0.28	0.12	0.60	0.02

Table 4.4 (continued).

	Mourning Warbler	Northern Flicker	Orange-crowned Warbler	Olive-sided Flycatcher	Oven Bird	Rose-breasted Grosbeak
	Function 1	Function 1	Function 1	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	-0.27	0.68	-0.06	-0.14	-0.64	-0.15
Tree Density (≥ 10 cm dbh)	0.07	0.14	-0.17	-0.13	0.31	0.06
DWM Density (≥ 10 cm dbh)	0.14	-0.24	-0.11	-0.08	1.00	0.03
DWM Frequency (< 10 cm dbh)	-0.17	0.31	-0.05	-0.05	-0.05	-0.37
DWM Frequency (< 5 cm dbh)	-0.06	-0.40	0.76	0.36	0.17	0.00
Shrub Frequency (≥ 3 m ht)	1.00	-0.42	-0.54	0.04	0.22	0.89
Shrub Frequency (≥ 1 m ht)	0.40	-0.05	-0.30	-0.13	0.16	0.35
Snag Frequency (< 10 cm dbh)	-0.11	0.26	-0.06	0.09	-0.38	-0.09
Herb Cover (%)	0.10	-0.01	0.20	1.00	0.06	0.05
Wilks' Lambda	0.84	0.61	0.66	0.87	0.79	0.52
df	1,22	3,20	2,21	1,22	1,22	2,21
P	0.049	0.018	0.013	0.084	0.026	0.001
Proportion Explained	0.17	0.39	0.34	0.13	0.21	0.48

Table 4.4(continued).

	Ruby-crowned Kinglet	Red-eyed Vireo	Ruffed Grouse	Song Sparrow	Solitary Vireo	Swainson's Thrush
	Function 1	Function 1	Function 1	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	0.32	-0.16	-0.31	0.12	1.00	-0.18
Tree Density (≥ 10 cm dbh)	-0.33	0.25	-0.08	0.43	-0.34	1.00
DWM Density (≥ 10 cm dbh)	-0.04	-0.01	0.14	0.34	-0.60	0.21
DWM Frequency (< 10 cm dbh)	0.12	-0.18	0.00	0.01	0.17	-0.37
DWM Frequency (< 5 cm dbh)	0.20	0.41	0.25	-0.12	-0.29	-0.23
Shrub Frequency (≥ 3 m ht)	0.12	0.17	0.62	0.03	-0.29	0.13
Shrub Frequency (≥ 1 m ht)	0.45	0.01	0.39	0.27	-0.04	0.07
Snag Frequency (< 10 cm dbh)	0.34	0.21	0.33	0.13	0.47	-0.01
Herb Cover (%)	0.15	0.36	0.24	0.01	-0.04	-0.24
Wilks' Lambda	0.46	0.43	0.65	0.40	0.88	0.71
df	4,19	5,18	3,20	3,20	1,22	3,20
P	0.003	0.006	0.031	<0.001	0.094	0.069
Proportion Explained	0.55	0.57	0.35	0.60	0.12	0.29

Table 4.4 (continued).

	Tennessee Warbler		Warbling Vireo	White-breasted Nuthatch	White-crowned Sparrow	Western Tanager
	Function 1	Function 2	Function 1	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	0.61	-0.44	-0.17	-0.15	-0.07	-0.19
Tree Density (≥ 10 cm dbh)	-0.42	0.15	-0.05	0.18	-0.38	-0.01
DWM Density (≥ 10 cm dbh)	-0.44	0.22	0.00	0.64	-0.18	0.26
DWM Frequency (< 10 cm dbh)	-0.16	-0.34	-0.13	0.09	0.00	-0.21
DWM Frequency (< 5 cm dbh)	-0.04	0.43	-0.14	0.11	0.66	-0.11
Shrub Frequency (≥ 3 m ht)	-0.01	0.41	1.00	0.05	0.14	0.47
Shrub Frequency (≥ 1 m ht)	-0.05	0.67	0.39	0.32	-0.06	1.00
Snag Frequency (< 10 cm dbh)	0.24	0.04	-0.24	0.42	-0.12	0.06
Herb Cover (%)	0.27	0.37	0.09	0.05	0.31	-0.22
Wilks' Lambda	0.15	0.47	0.80	0.75	0.26	0.82
df	12,45	6,38	1,22	2,21	4,19	1,22
P	<0.000	0.027	0.031	0.049	<0.001	0.039
Proportion Explained	0.69	0.46	0.20	0.25	0.74	0.18

Table 4.4 (continued).

	Wilson's Warbler	Winter Wren	White-throated Sparrow		White-winged Crossbill	Western Wood Peewee
	Function 1	Function 1	Function 1	Function 2	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	-0.12	-0.24	0.61	-0.30	-0.14	1.00
Tree Density (≥ 10 cm dbh)	-0.08	1.00	-0.03	0.26	0.77	-0.28
DWM Density (≥ 10 cm dbh)	0.29	0.28	-0.51	0.11	0.06	-0.30
DWM Frequency (< 10 cm dbh)	-0.28	-0.29	0.18	-0.06	-0.20	0.14
DWM Frequency (< 5 cm dbh)	0.01	-0.31	-0.38	0.09	0.04	-0.23
Shrub Frequency (≥ 3 m ht)	0.45	0.08	0.29	0.31	-0.20	-0.14
Shrub Frequency (≥ 1 m ht)	1.00	-0.10	0.04	0.31	-0.50	0.07
Snag Frequency (< 10 cm dbh)	0.09	-0.06	0.32	0.59	-0.16	0.16
Herb Cover (%)	-0.14	-0.19	-0.13	0.07	0.08	0.02
Wilks' Lambda	0.86	0.80	0.31	0.68	0.70	0.33
df	1,22	1,22	9,44	4,40	2,21	1,22
P	0.068	0.027	0.005	0.106	0.022	<0.001
Proportion Explained	0.14	0.20	0.56	0.35	0.31	0.67

Table 4.4 (continued).

	Yellow-bellied Sapsucker	Yellow Warbler	Yellow-rumped Warbler
	Function 1	Function 1	Function 1
Snag Density (≥ 10 cm dbh)	-0.59	0.19	-0.03
Tree Density (≥ 10 cm dbh)	0.41	-0.35	-0.11
DWM Density (≥ 10 cm dbh)	1.00	-0.28	0.19
DWM Frequency (< 10 cm dbh)	-0.17	0.04	-0.38
DWM Frequency (< 5 cm dbh)	0.13	0.01	-0.02
Shrub Frequency (≥ 3 m ht)	0.09	0.63	0.51
Shrub Frequency (≥ 1 m ht)	0.34	0.44	1.00
Snag Frequency (< 10 cm dbh)	-0.36	0.00	0.20
Herb Cover (%)	-0.14	0.04	-0.07
Wilks' Lambda	0.78	0.41	0.80
df	1,22	3,20	2,21
P	0.021	<0.001	0.092
Proportion Explained	0.22	0.59	0.20

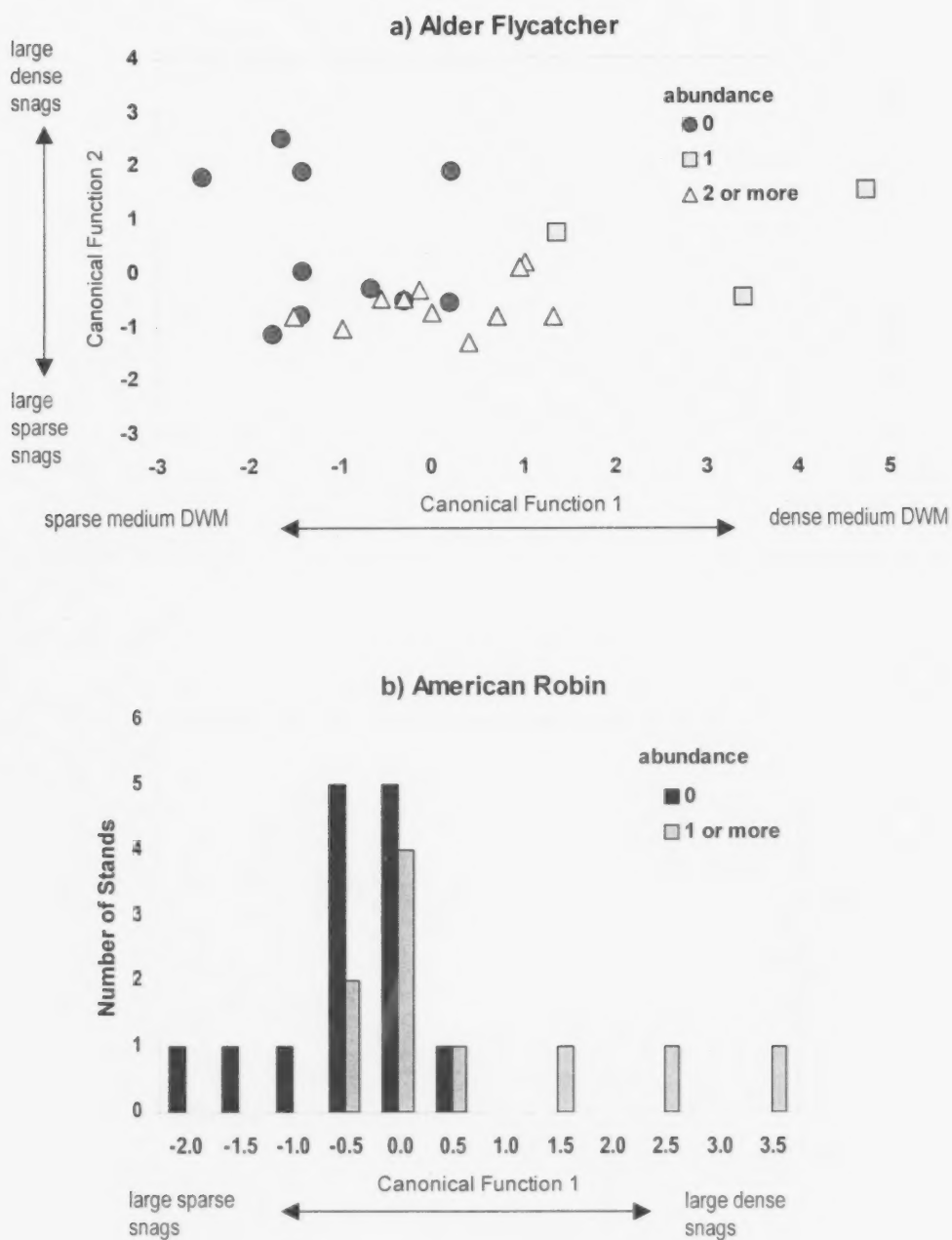


Figure 4.4. The separation observed between abundance categories for a) alder flycatcher and b) American robin across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

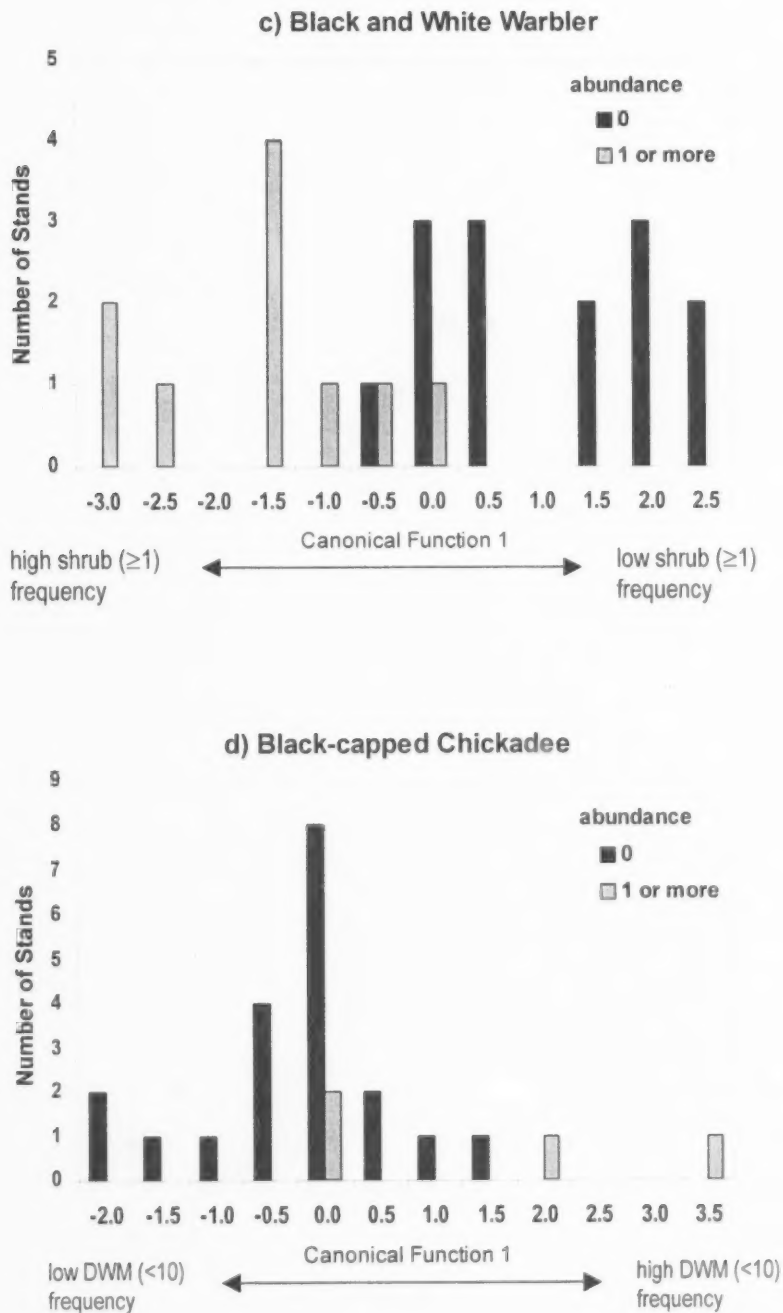


Figure 4.4 continued. The separation observed between abundance categories for c) black and white warbler and b) black-capped chickadee across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

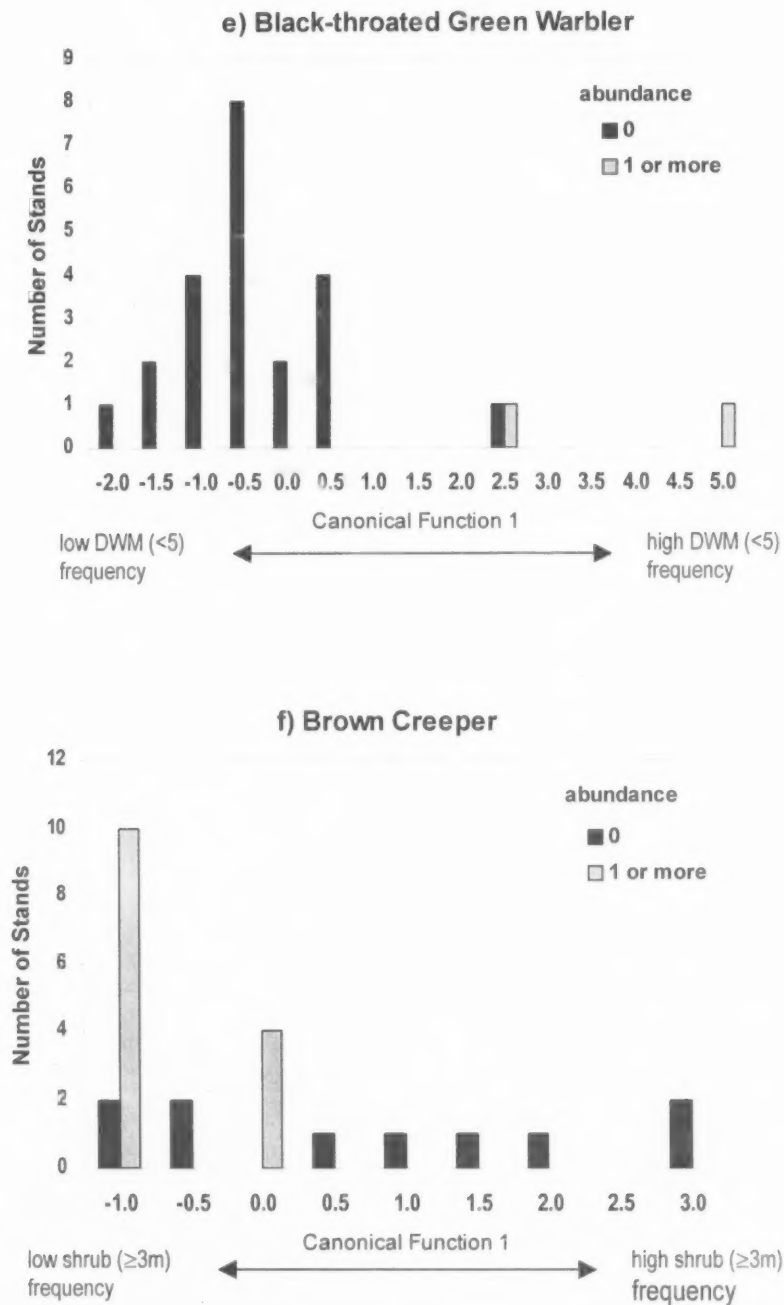


Figure 4.4 continued. The separation observed between abundance categories for e) black-throated green warbler and f) brown creeper across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

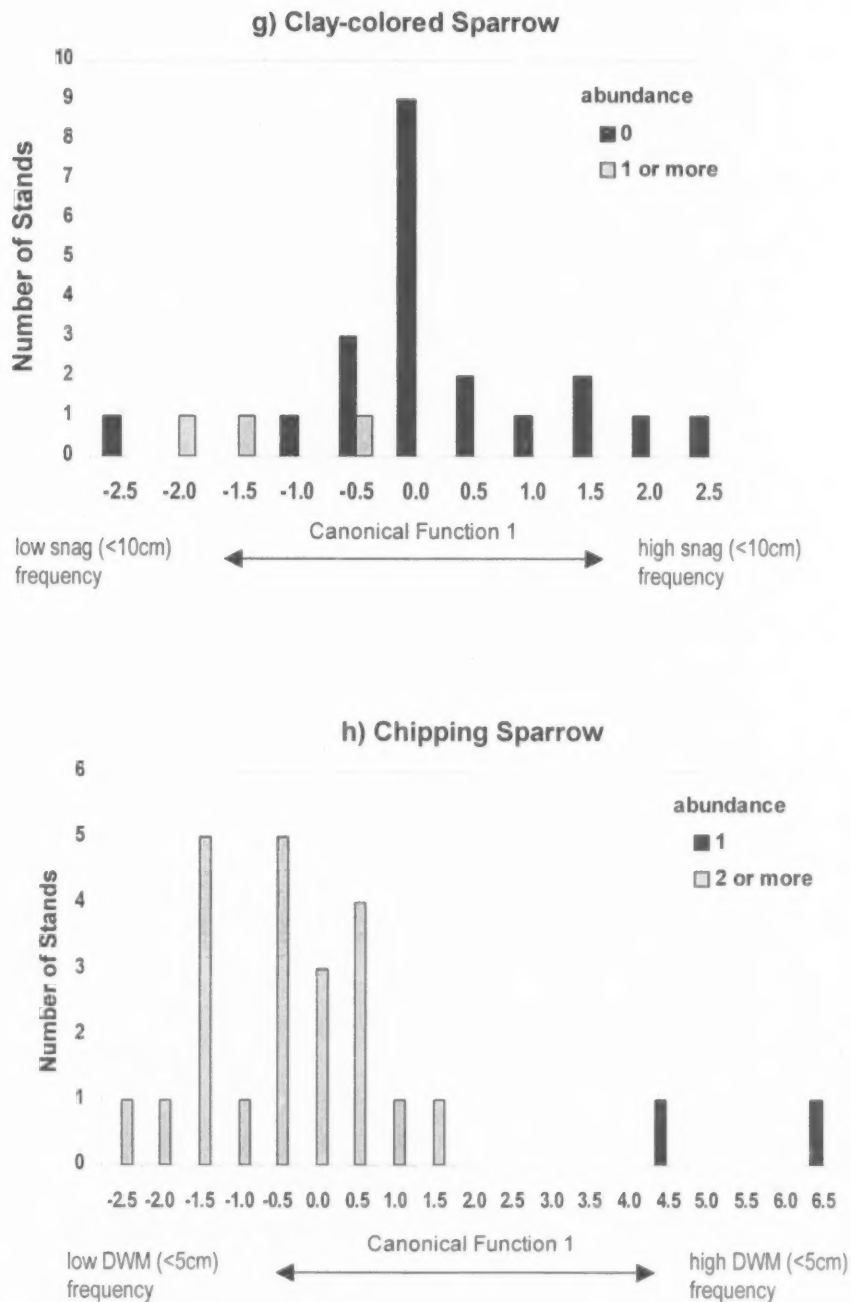


Figure 4.4 continued. The separation observed between abundance categories for g) clay-colored sparrow and h) chipping sparrow across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

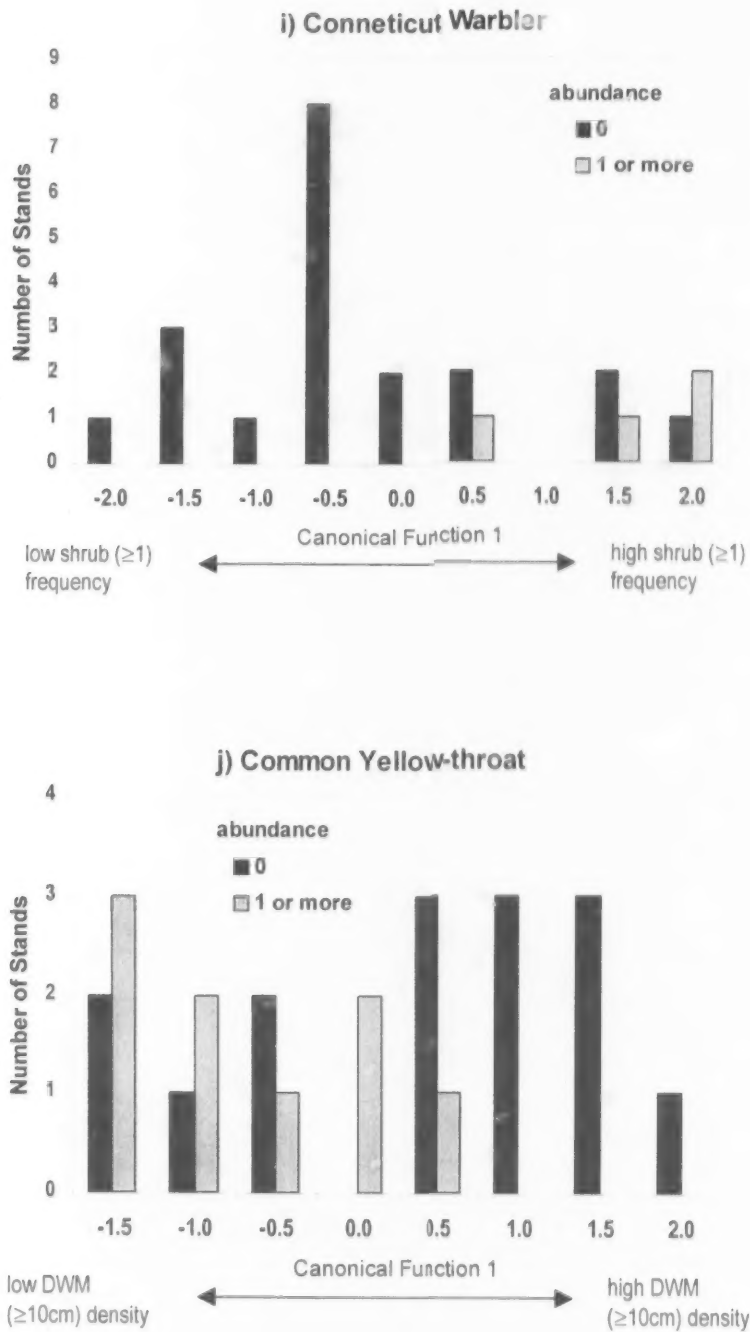


Figure 4.4 continued. The separation observed between abundance categories for i) Connecticut warbler and j) common yellow-throat across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

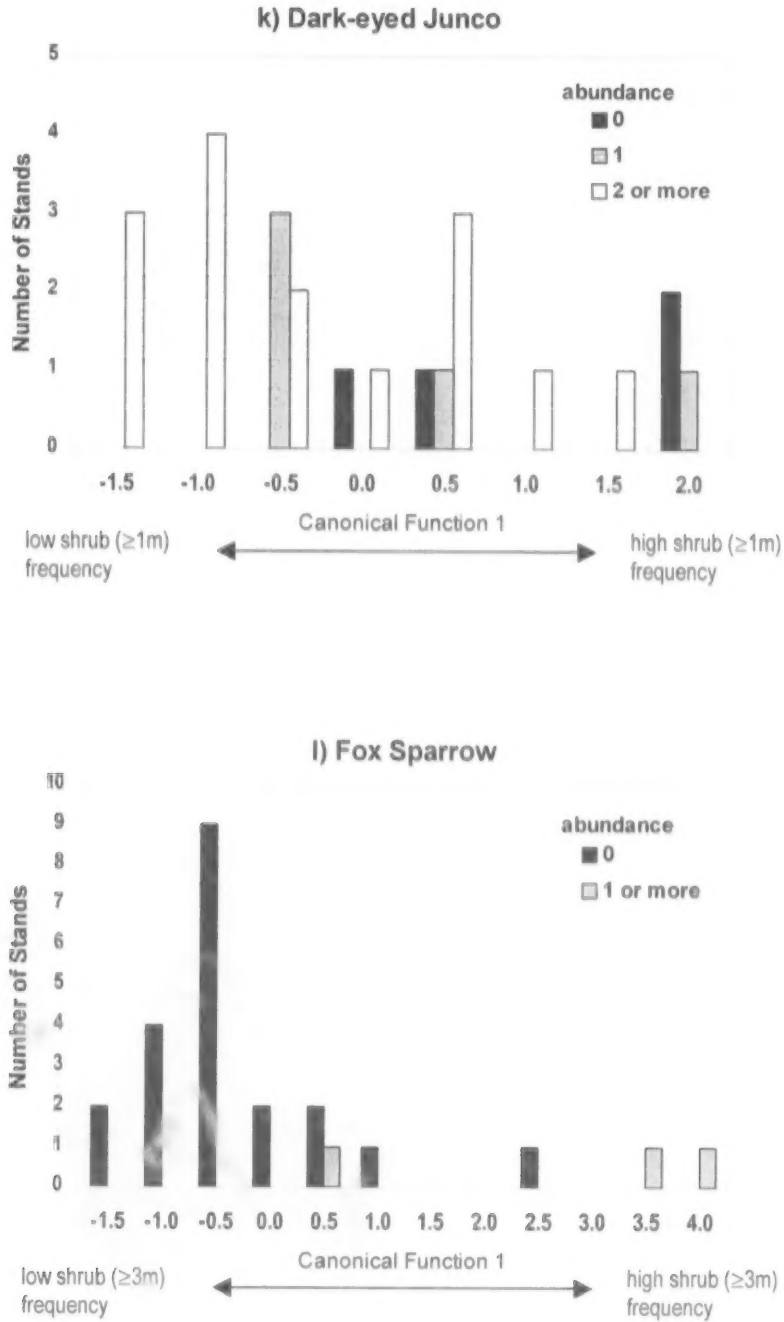


Figure 4.4 continued. The separation observed between abundance categories for k) dark-eyed junco and l) fox sparrow across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

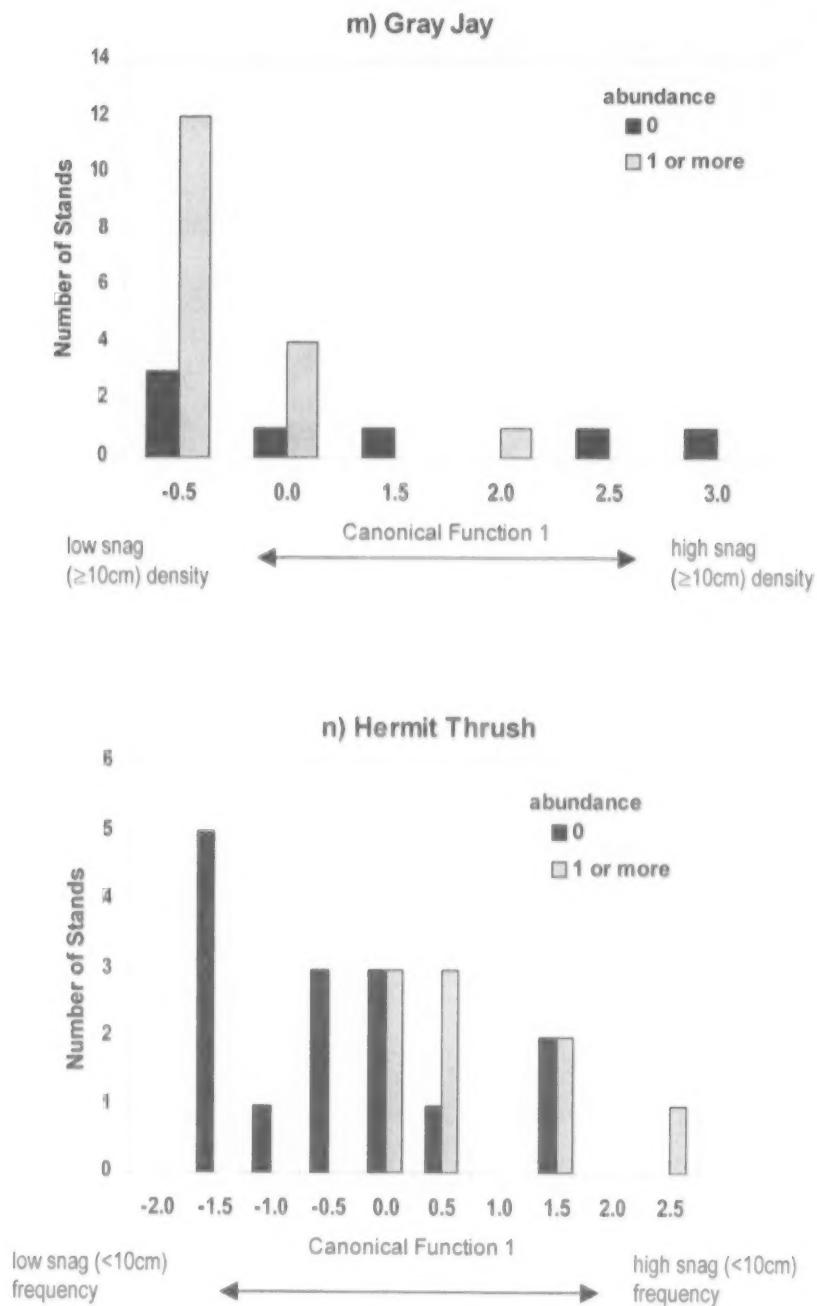


Figure 4.4 continued. The separation observed between abundance categories for m) gray jay and n) hermit thrush across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

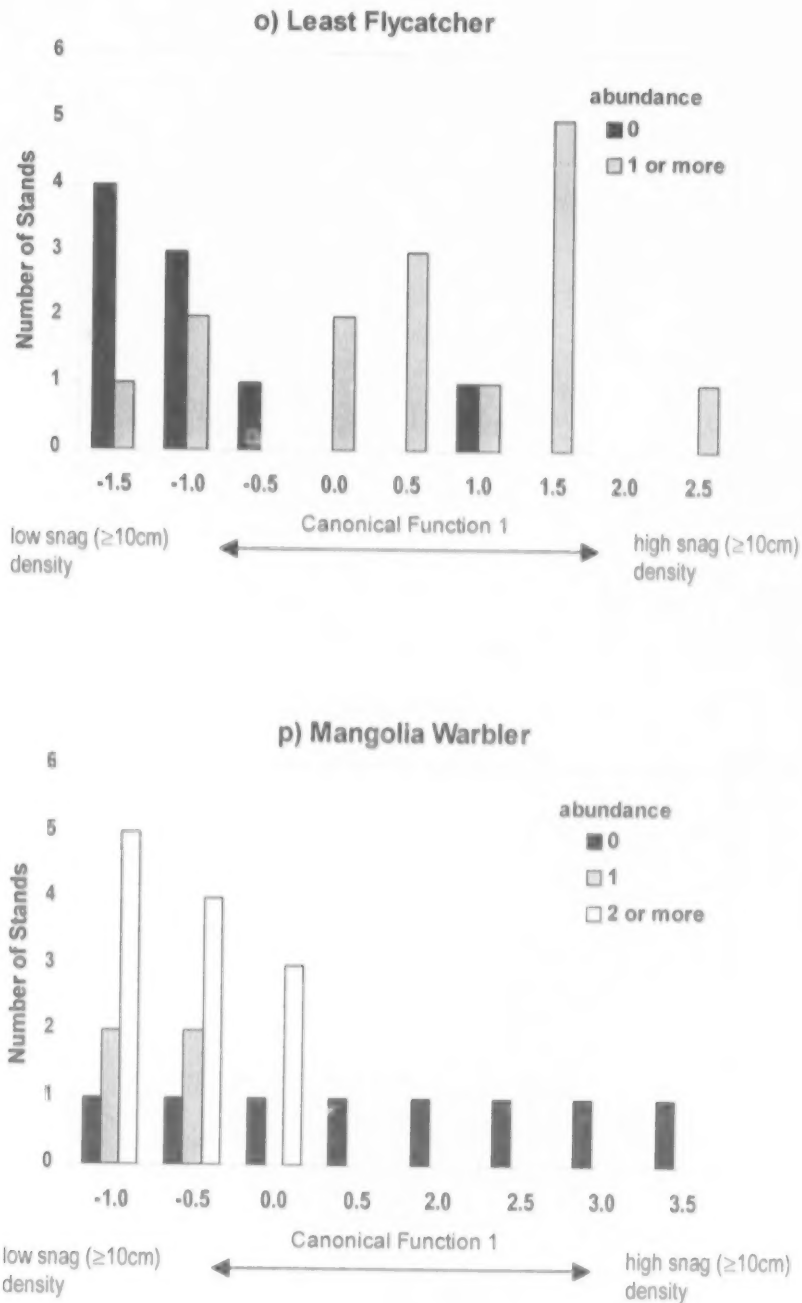


Figure 4.4 continued. The separation observed between abundance categories for o) least flycatcher and p) mangolia warbler across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

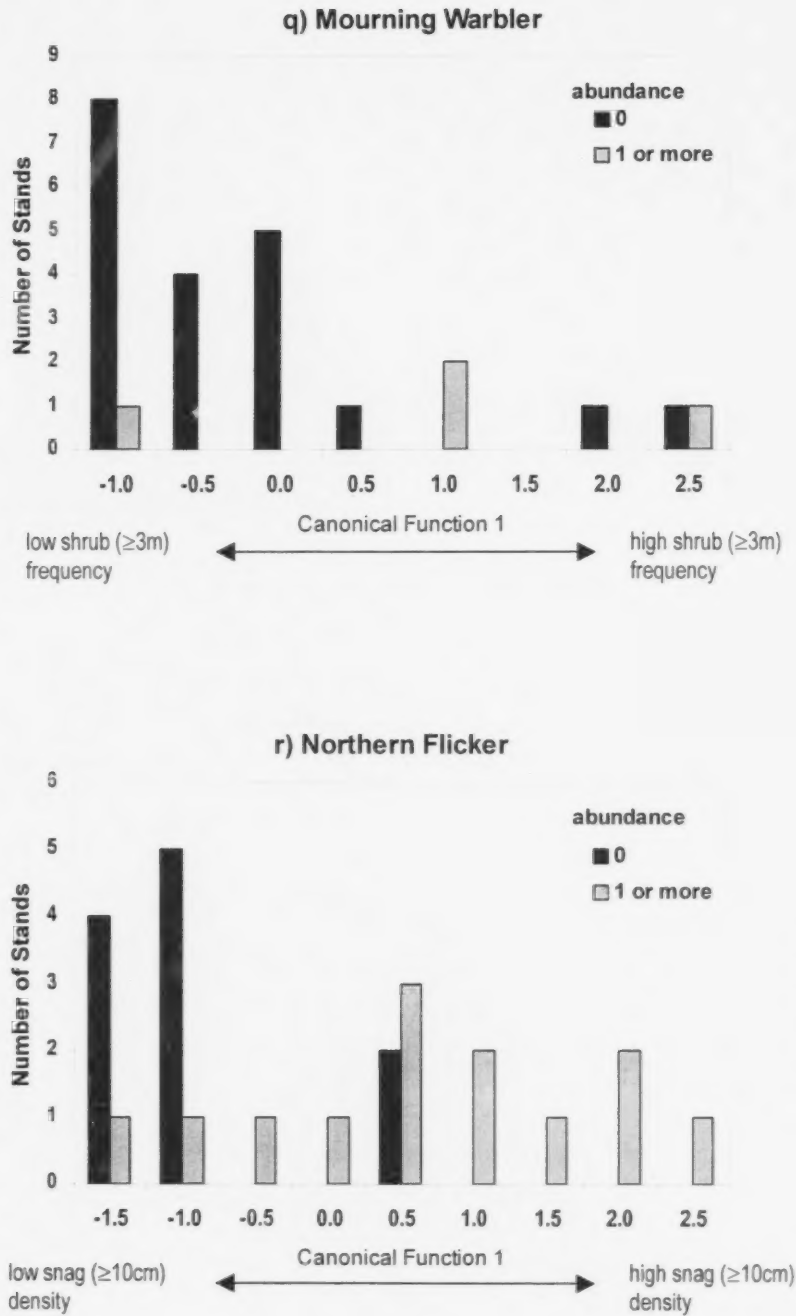


Figure 4.4 continued. The separation observed between abundance categories for q) mourning warbler and r) northern flicker across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

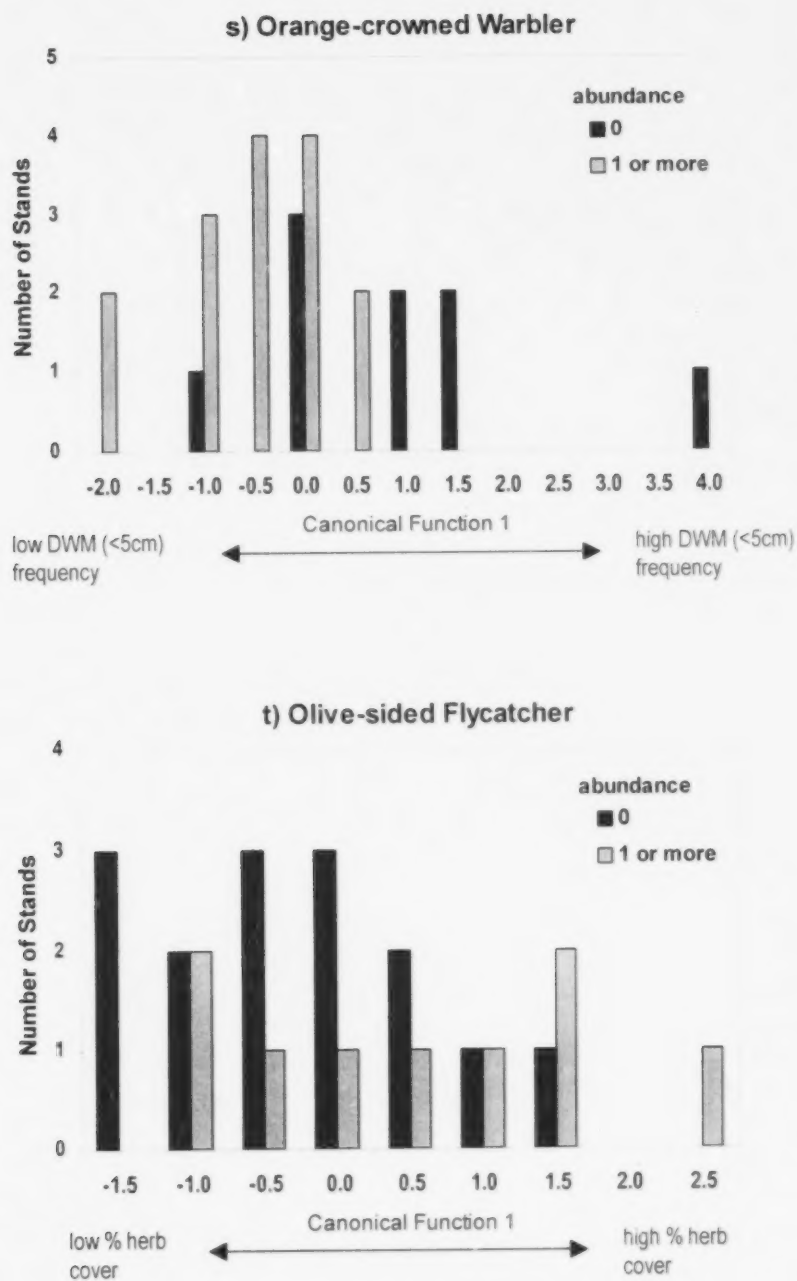


Figure 4.4 continued. The separation observed between abundance categories for s) orange-crowned warbler and t) olive-sided flycatcher across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.



Figure 4.4 continued. The separation observed between abundance categories for u) oven bird and v) rose-breasted grosbeak across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

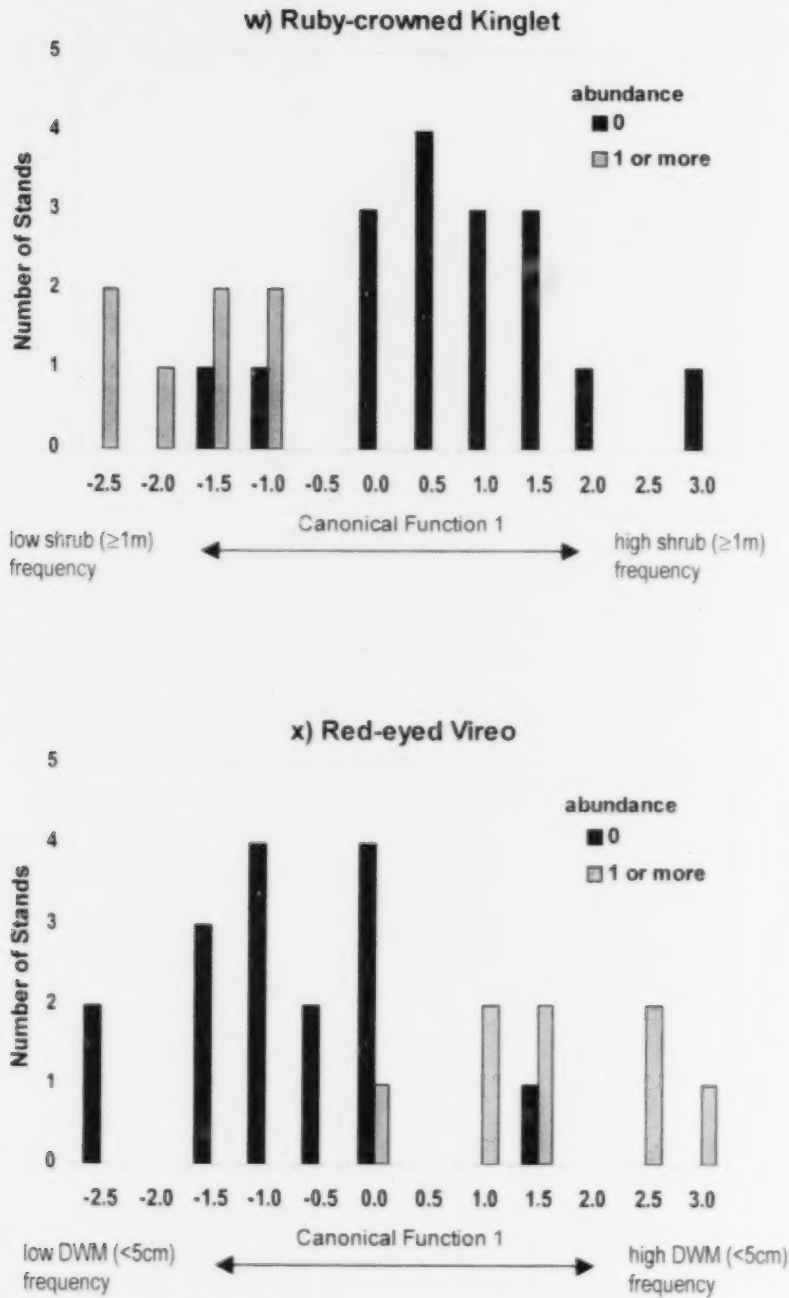


Figure 4.4 continued. The separation observed between abundance categories for w) ruby-crowned kinglet and x) red-eyed vireo across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

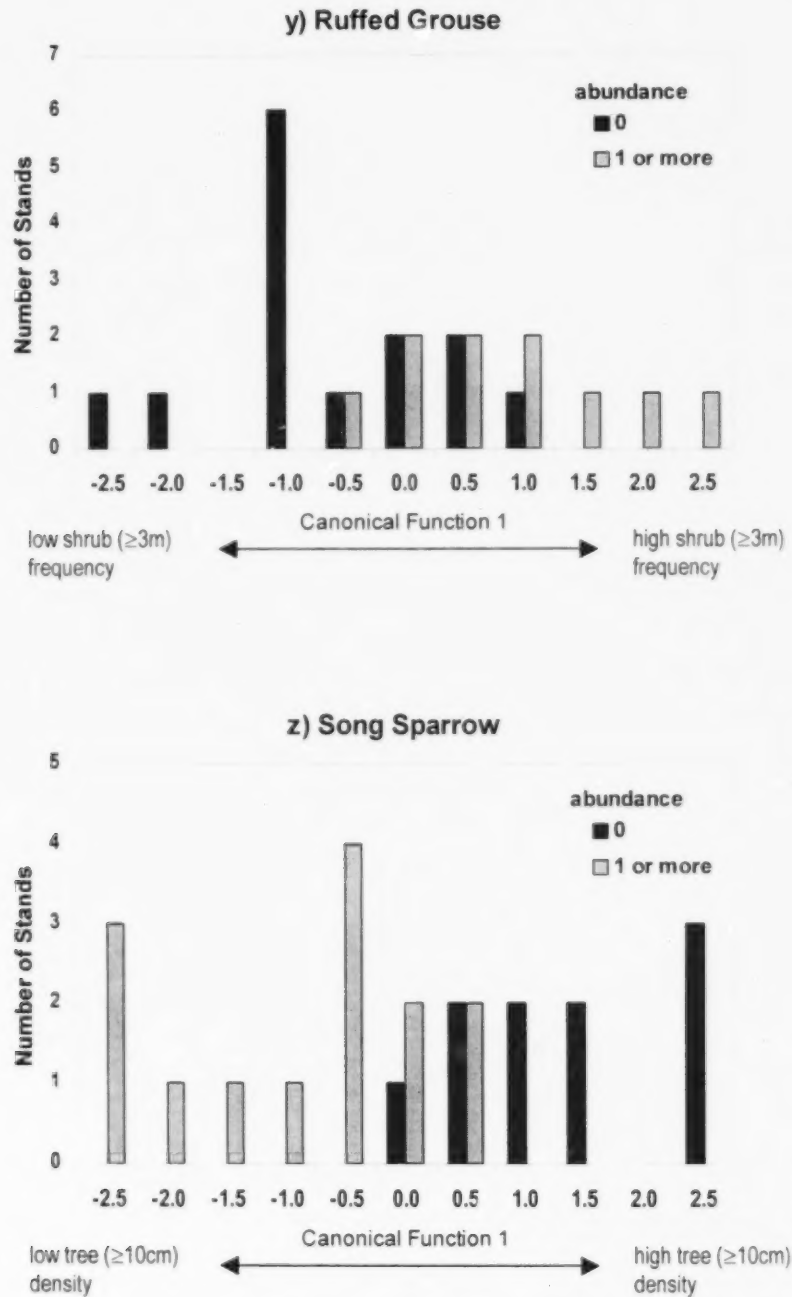


Figure 4.4 continued. The separation observed between abundance categories for y) ruffed grouse and z) song sparrow across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

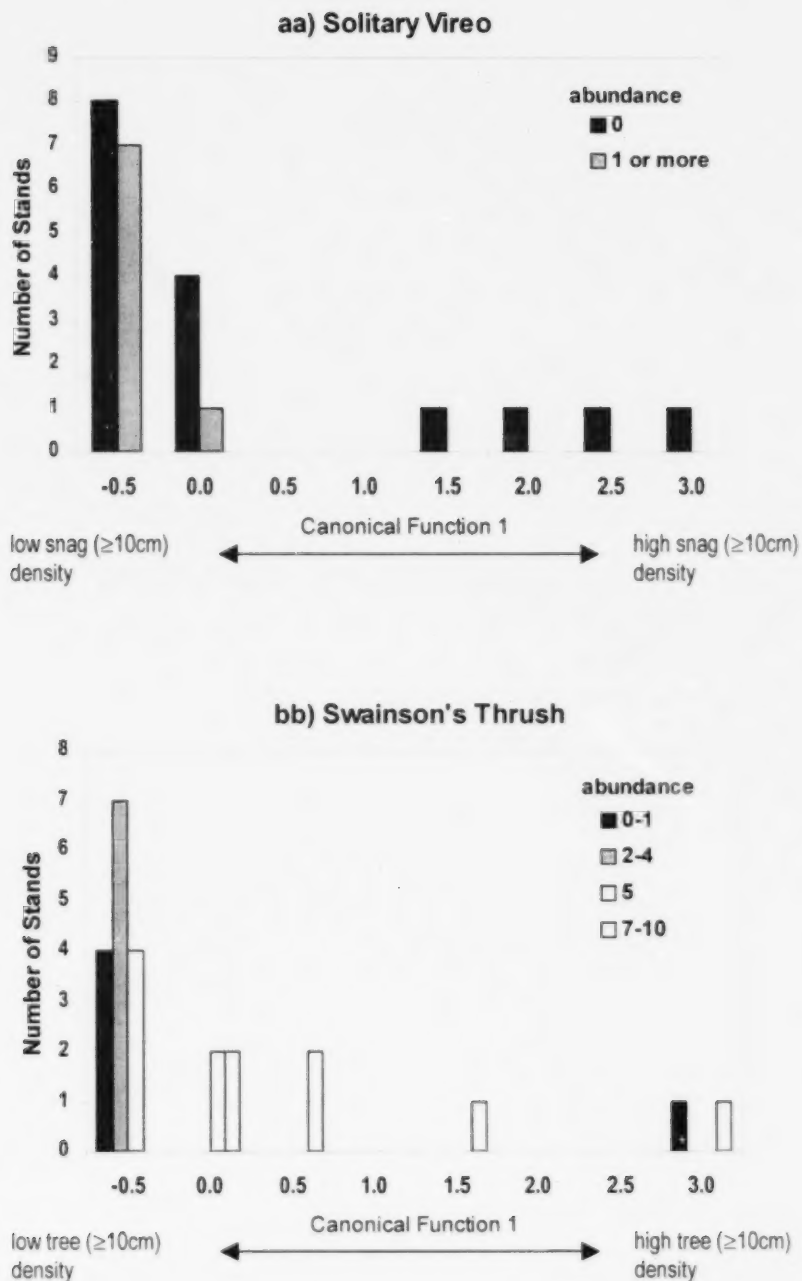


Figure 4.4 continued. The separation observed between abundance categories for aa) solitary vireo and bb) Swainson's thrush across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

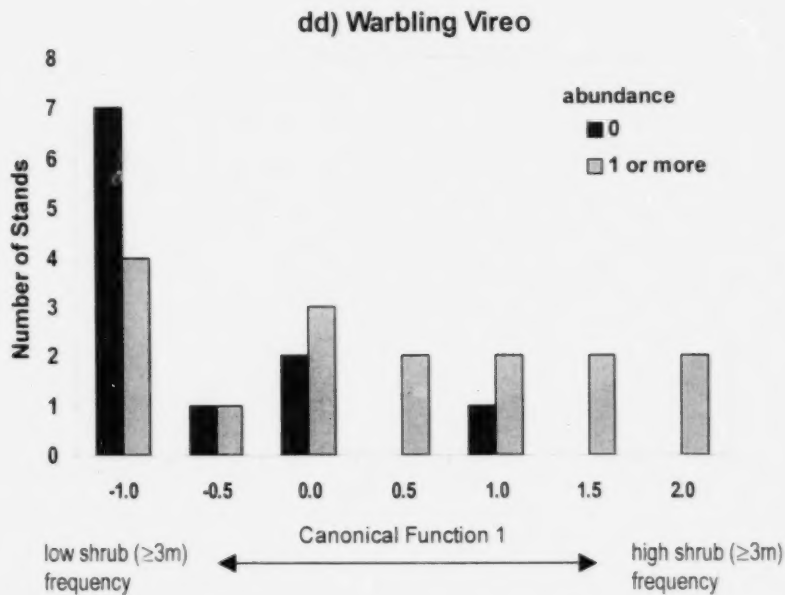
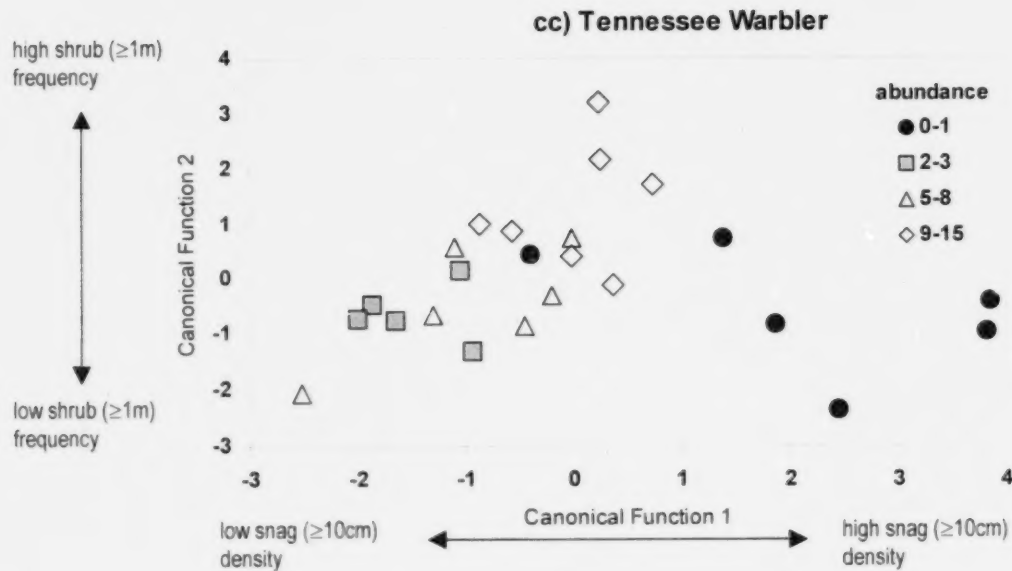


Figure 4.4 continued. The separation observed between abundance categories for cc) Tennessee warbler and dd) warbling vireo across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

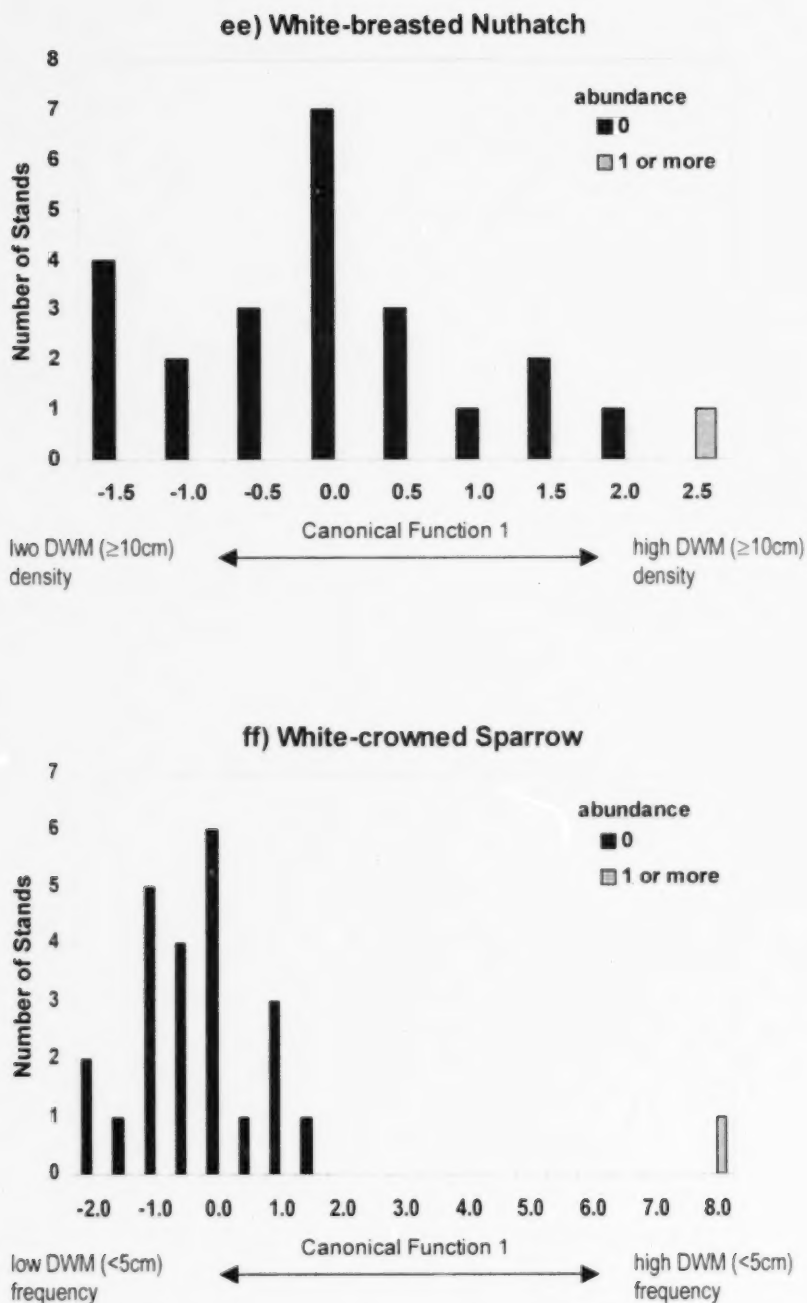


Figure 4.4 continued. The separation observed between abundance categories for ee) white-breasted nuthatch warbler and ff) white-crowned sparrow across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

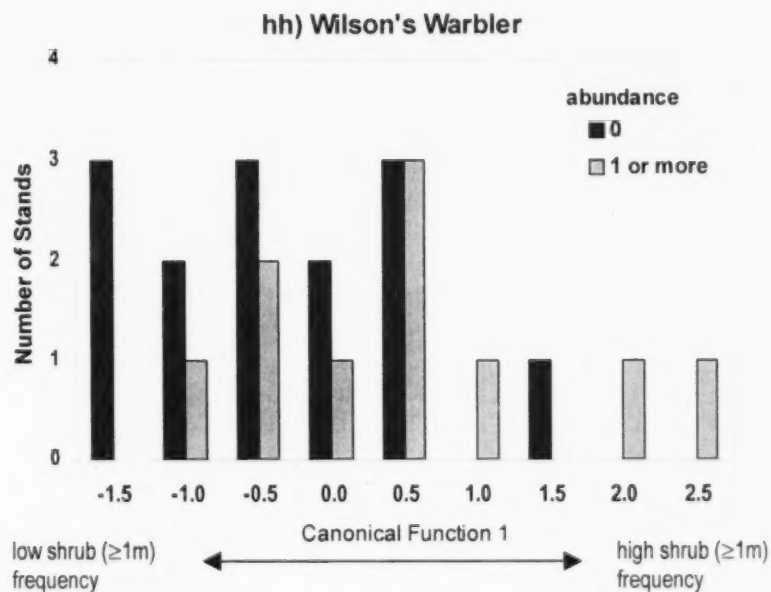
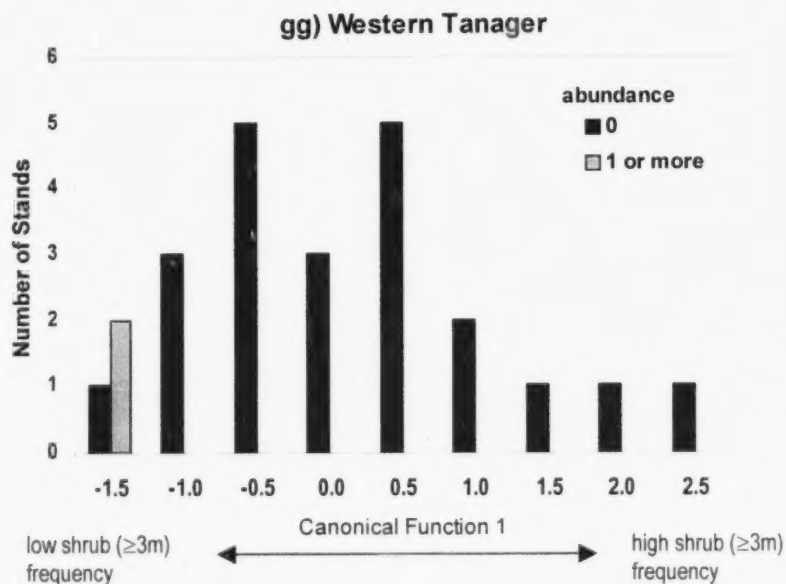


Figure 4.4 continued. The separation observed between abundance categories for gg) western tanager and hh) Wilson's warbler across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

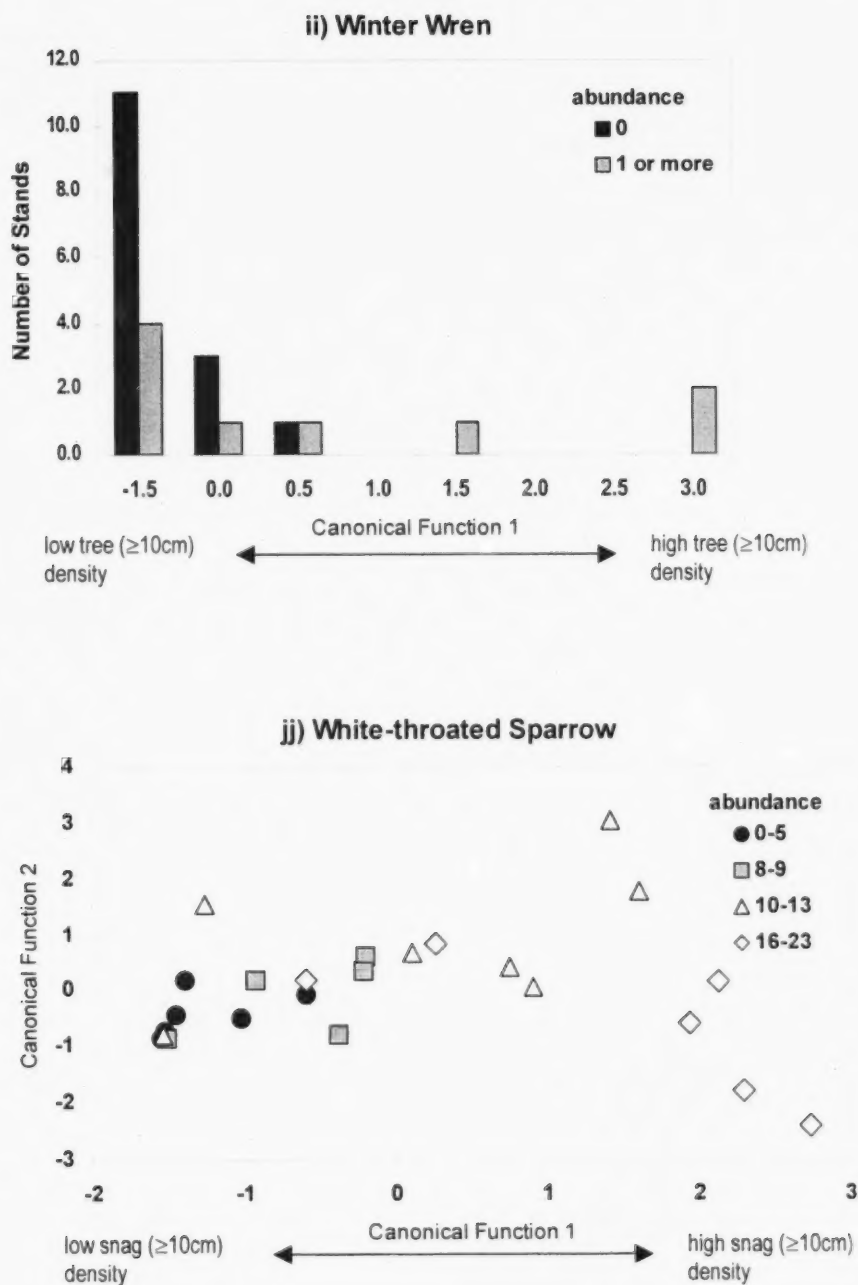


Figure 4.4 continued. The separation observed between abundance categories for ii) winter wren and jj) white-throated sparrow across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

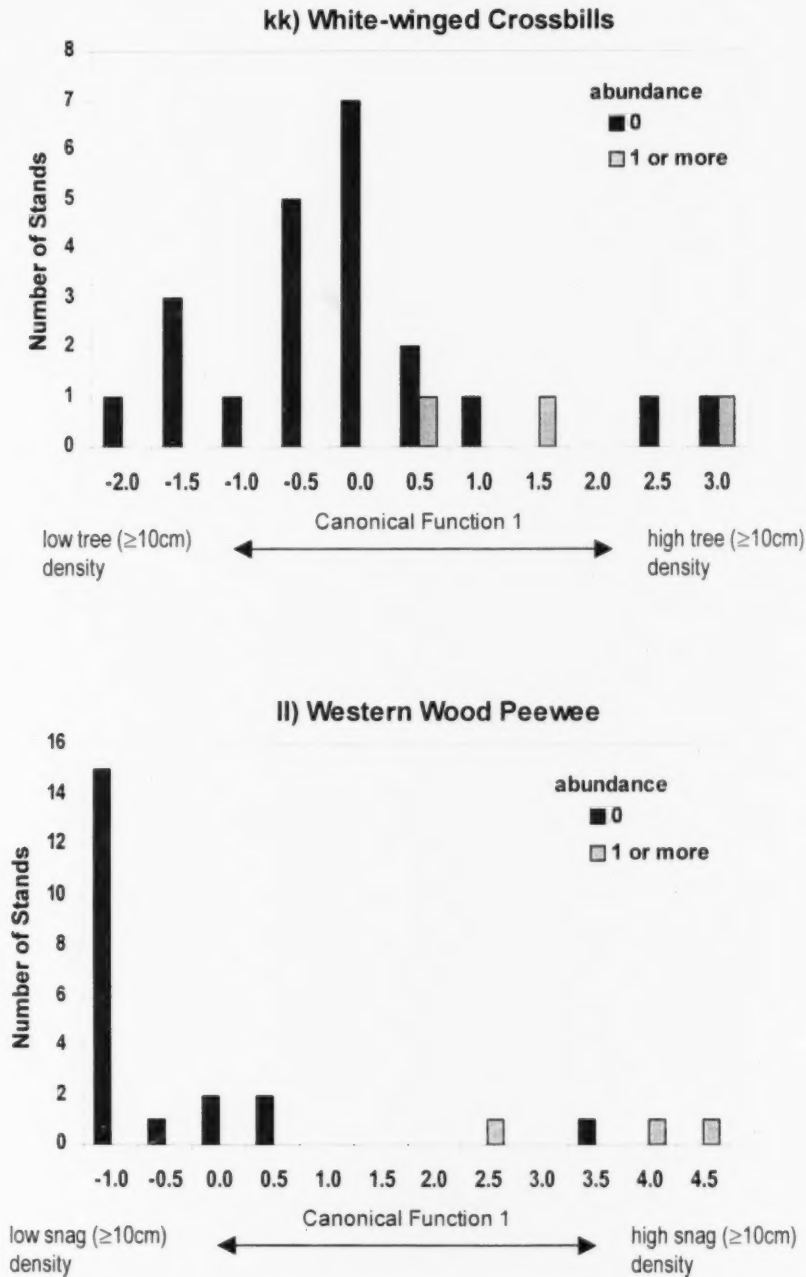


Figure 4.4 continued. The separation observed between abundance categories for kk) white-winged crossbills and ll) western wood peewee across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

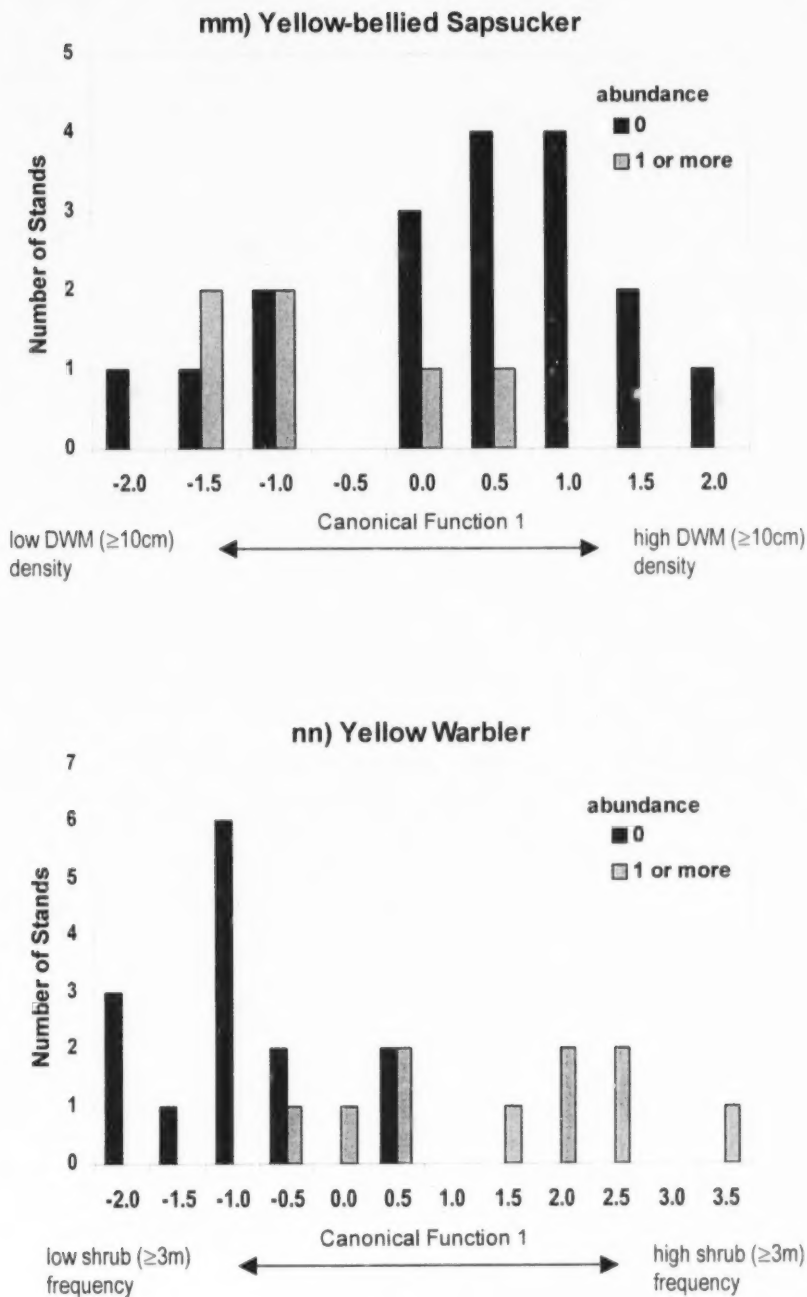


Figure 4.4 continued. The separation observed between abundance categories for mm) yellow-bellied sapsucker and nn) yellow warbler across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes ($N=24$). Data points are based on canonical discriminant score.

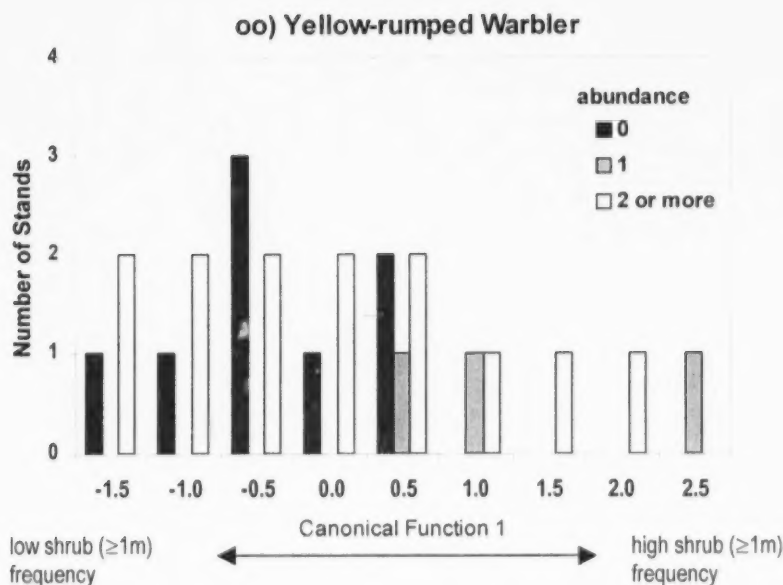


Figure 4.4 continued. The separation observed between abundance categories for oo) yellow-rumped warbler across all burn and harvest stands in 1993, 1980, and 1969 disturbance age-classes (N=24). Data points are based on canonical discriminant score.

Harvest Guidelines for Birds Affected by Harvesting

The abundance of nine species were affected by harvesting in the 1993 age-class. To determine harvest guidelines for those species, abundance in the 1993 burns was compared to the other disturbance age-classes. The vegetation attribute that was correlated to a species for the disturbance age-class at which abundance levels were equivalent to the 1993 burn stands were used as harvest guidelines. For example, abundance of song sparrows in the 1980 burn stand was equivalent to fire disturbed stands in 1993 (Mann-Whitney test; Table 4.5). Given that this species was most highly correlated with large diameter trees, it was assumed that guidelines at the 1993 harvest site for large diameter trees should follow the characteristics of large diameter trees in the 1980 harvest stands.

Table 4.5. Comparison of bird abundance between 1993 burn stands and the other disturbance age-classes for those species affected by harvesting as determined in Year 1 of study. A non-significant difference indicates the disturbance age-classes at which abundance levels were equivalent to 1993 burn levels.

Species	Year 1					p-value	vegetation variable
	1993 Burn	1980 Burn	1980 Harvest	1969 Burn	1969 Harvest		
Song Sparrow	2	9	-	-	-	0.222	tree (≥ 10 cm) density
Northern Flicker	9	5	-	-	-	0.237	snag (≥ 10 cm) density
White-throated Sparrow	75	-	51	-	-	0.189	snag (≥ 10 cm) density
Magnolia Warbler	0	-	4	-	-	0.131	snag (≥ 10 cm) density
Common Yellowthroat	5	-	3	-	-	0.544	DWM (≥ 10 cm) density
Least Flycatcher	9	-	-	-	5	0.372	snag (≥ 10 cm) density
Alder Flycatcher	0	-	-	-	11	0.131	DWM (< 5 cm) frequency
Tennessee Warbler	2	-	-	-	22	0.036	snag (≥ 10 cm) density
Western Wood Peewee	18	-	-	-	0	0.046	snag (≥ 10 cm) density

4.4 Discussion

Effects of Timber Harvest on Small Mammals

According to the previous, although separate, studies on post-fire and post-harvest disturbance (Kirkland 1977; Fox 1983), little difference would be expected between abundance and species richness of small mammals between the two disturbance types.

In this study, overall abundance of the small mammal community was not affected a great deal by harvesting. The only significant difference occurred in year 1 of study where total abundance was twice the number in 1993 harvest stands as compared to burn stands and species richness was greater in harvest stands. These differences disappeared with time since disturbance.

Although difficult to compare to other studies due to differences in time since disturbance and habitat type, the pattern of abundance showed similar trends to previous studies (Kirkland 1977). Total abundance in both disturbance types and both years of study started off at a relatively moderate abundance in the 1993 age-class, decreased slightly in the 1980 age-class, and, except for a decrease in abundance from the 1980 to 1969 harvest stands in year 1 of study, increased by the 1969 year of disturbance.

Since small mammals are mainly ground dwelling species, the loss of vertical structure associated with harvesting might have very little affect on these species. Indeed, red-backed vole abundance was associated with greater densities of coarse DWM and percentage of herb cover.

These results are consistent with other studies (Hayes and Cross 1987; Roy *et al.* 1995) that found coarse DWM to be an important factor for small mammal species. Both of these forest attributes might provide ground cover for protection from predation and coarse DWM might also provide suitable nesting sites.

However, deer mouse abundance was associated with low and moderate large diameter tree densities. Although this might intuitively seem like a structure greatly affected by harvesting, in comparison to burn stands, live trees were not initially affected by harvesting (Chapter 3, section 3.3.1 Large Diameter Trees). In mixed wood deciduous forests of Virginia, Wolff and Hurlbutt (1982) found that deer mice used tree refuges ten times more often than ground refuges. This may account for the association between deer mice and large diameter trees in this study.

Effects of Timber Harvest on Birds

As with small mammals, previous studies indicate that there could be similarities between fire and timber harvest disturbance in terms of abundance and species richness (Fox 1983). Studies investigating the effects of clearcut harvesting and wildlife on abundance and species richness found that the number and species richness of birds increased over time and often increased to levels higher than in mature forests after both disturbance types (Kavanagh *et al.* 1985; DesGranges & Rondeau 1992).

In this study, total abundance was higher in burn than harvest stands in the 1993 treatment. Although abundance increased in both treatment types in the 1980 age-class, it increased sharply in the 1980 harvest treatments to levels above those in the 1980 burn stands. Abundance continued to increase in the 1969 burn stands while it decreased in the 1969 harvest stands to levels below the 1969 burn treatment. Although the overall pattern of abundance for birds was very similar in both years of study, significant differences in abundance occurred only in Year 2 of study where harvest and burns differed in the 1993 and 1969 age-classes. An increase in sampling intensity may have shown the same results in Year 1 of study.

Convergence in abundance for the two treatment types followed by divergence as time since disturbance increased demonstrates how important a chronosequence study of this type is to determine if differences exist between disturbance types. It appears that something done to the habitat during timber harvesting persists long after the disturbance event to affect overall

abundance of birds. And, perhaps more importantly, long after the time at which most harvest management techniques would consider a second pass through a management area, thus leaving few naturally disturbed areas to repopulate harvest disturbed sites. It should also be noted that the sampling areas in this study were small and surrounded by naturally disturbed forest. Despite this, the harvested areas were not repopulated, once again indicating that they were unsuitable, or at least, not preferred habitat.

Although a number of individual bird species were found to be affected by timber harvesting in all age-classes, species loss also may be imminent for those species whose abundance remained low after the rotation age used in the management area, regardless of whether or not a species's abundance departed from the natural disturbance scenario. For example, species with a naturally low abundance in the 1993 burn treatment that increased to significantly greater abundance in the 1980 burn treatment could be affected by a rotation age of less than 16 years, if this rotation age is shorter than what occurs naturally. Species loss may not be imminent for those species whose abundance will be increased by a short rotation age, but competitive exclusion due to increased abundance of a species could be equally harmful to the system.

According to the Year 1 bird data, the Swainson's thrush and warbling vireo could experience a decrease in abundance with a rotation age of less than 16 years. The Swainson's thrush also could see a decrease in abundance with a rotation age of less than 26 years. The Year 2 bird data demonstrated that the Tennessee warbler and, once again, the warbling vireo could see a decrease in abundance across the landscape with a rotation age less than 16 years while the song sparrow could experience an increase in abundance with this rotation age. The dark-eyed junco could experience a decrease in abundance with a rotation age of less than 26 years while the Connecticut warbler might experience an increase in abundance with this rotation age. Species whose abundance remains low until the 1969 age-class will likely be greatly impacted by the rotation age used in many harvest management techniques (approximately 16 years in this study area; Pers Comm. J.P. Beleche).

Of course, the large time gaps between treatment age-classes in this study make it impossible to determine an appropriate rotation age. However, this information does highlight the importance of the time scale of harvesting under a natural disturbance management regime.

Bird Abundance in Relation to Forest Community Attributes

Almost all species of birds had significant correlations with forest attributes measured in this study. This might indicate that virtually all species are dependent on specific habitat attributes, that is, there are few generalist species. The following discussion focuses on those species whose abundance was affected by harvesting, but it should be kept in mind that incorporating harvest recommendations might in turn affect those species that were not determined to be affected by harvesting in this study. It is vitally important that incorporation of this information is followed by a monitoring system.

Not surprisingly, the majority of species affected (either low or high abundance) by harvesting in the 1993 age-class were most strongly correlated with large diameter ($\geq 10\text{cm}$) snag densities. These included the northern flicker, white-throated sparrow, magnolia warbler, least flycatcher, Tennessee warbler, and western wood peewee. All, but one of these species, the least flycatcher, recovers by the 1980 treatments. However, to reduce the affects of harvesting immediately following disturbance, it is necessary to make changes to harvesting techniques at the time of disturbance. This is particularly important under a timber management regime that includes harvesting adjacent leaves within 16 years of the first pass.

A comparison between abundance of species in 1993 burn stands affected by harvesting and abundance of these species in other disturbance treatments gave an indication of the vegetation characteristics necessary to recover 1993 harvest disturbed sites to their naturally disturbed counterparts. These analyses indicated that all but the Tennessee warbler and the western wood peewee could possibly be maintained by manipulation at the time of harvest.

Abundance of the song sparrow and northern flicker could be maintained at levels similar to 1993 natural disturbance levels by maintaining abundance of large diameter snag and tree densities at 1980 burn levels at the time of harvest. Snag densities should equal 49.5 ± 15.9 snags/ha. The average diameter of snags would be $22.4 \pm 0.6\text{cm}$ ranging between 10.1 and 68.1cm. Snags would be spatially homogenous. The majority of snags (37.8%) would be in decay stage 3, followed by stage 4 (27.4%), stage 5 (17.0%), stage 2 (9.7%), and stage 6 (8.0%). Cavity density should equal 0.9 ± 0.5 cavities/ha. Tree densities should be maintained at 1.1 ± 0.4 trees/ha. The average diameter of trees would be $29.6 \pm 9.6\text{cm}$ ranging between 10.7 and 45.9cm.

Relative to the 1993 fire disturbed stands, abundance of the white-throated sparrow, magnolia warbler, and common yellowthroat recovered with large diameter snag and coarse DWM densities comparable to the 1980 harvest stands. This would mean maintaining snag densities at a minimum of 4.2 ± 2.1 snags/ha with an average diameter of 29.2 ± 1.1 cm ranging between 10.7 and 64.0 cm. Snags would be spatially homogenous. The majority of snags (60%) would be in decay stage 5, followed by stage 6 (23.3%), stage 4 (8.7%), stage 3 (5.1%), and stage 2 (2.6%). Cavity density should equal 0.9 ± 0.6 cavities/ha. To maintain 1993 fire disturbance abundance levels for the common yellowthroat, density of coarse DWM should range from 0.04 ± 0.005 pieces/7m up to 0.35 ± 0.15 pieces/7m in the following decay category: 22.2% in stage 1, 42.2% in stage 2, 15.6% in stage 3, 6.7% in stage 4, 4.4% in stage 5, 2.2% in stage 6, 6.7 in stage 7. However, a caveat must accompany this recommendation. Managing harvest stands for low densities of coarse DWM might conserve abundance of one species in the 1993 harvest stands, but management strategies must consider how this will affect future levels of DWM in a system that is virtually devoid of snags, and thus, a source of coarse DWM as time since disturbance increases. Given that the abundance of the common yellowthroat recovers in the 1980 age-class treatments, it is suggested that management maintain the coarse DWM densities found in this study in the 1993 harvest stands; 0.54 ± 0.13 pieces/7m.

Another two species, the least flycatcher and alder flycatcher, could be sustained by following large diameter snag and fine DWM characteristics found in the 1969 harvest stands. This would mean maintaining snag densities at a minimum of 4.3 ± 0.5 snags/ha with an average diameter of 25.6 ± 2.0 cm ranging between 10.7 and 60.7 cm. Snags would be spatially homogenous. The majority of snags (40.2%) would be in decay stage 5, followed by stage 6 (26.2%), stage 4 (21.6%), stage 3 (6.6%), stage 1 (4.1%), and stage 2 (1.4%). Cavity density should equal 0.6 ± 0.2 cavities/ha. Fine DWM should be maintained at 3.9 ± 0.5 pieces/m.

Two species, the Tennessee warbler and western wood peewee, appear not to be maintained by the previous harvest recommendations. The Tennessee warbler was correlated with low densities of snags, therefore its abundance was inflated by harvesting. Increasing snag densities at the time of harvesting would possibly lower abundance of Tennessee warblers in the years immediately following disturbance, but other than data on snag densities immediately following fire disturbance there is no indication from this study what minimum level of snag

densities will maintain natural abundance levels of this species. However, of the two scenarios, it is more desirable to have a species whose abundance is increased by harvesting assuming that there is no competitive exclusion occurring with another species. The western wood peewee appears to be highly sensitive to high snag densities as it is absent from burns and harvests in all age-classes except for the 1993 burns. This species would likely become at least locally extinct under a management regime that included harvesting and fire suppression.

For species that were affected by harvesting in the 1980 and 1969 disturbance age-classes, recommendations for changes to these habitats can be made, but since manipulation of harvest stands occurs at the time of harvest or within the first few years (replanting, herbicide application, thinning), this information is likely only useful in combination with a modelling program that can reasonably predict succession forward and backward.

These harvest recommendations give guidelines on how to manage for minimum acceptable abundances of bird species as determined by natural disturbance levels. Whenever possible, it is recommended that forest management strategies approximate the vegetation characteristics as documented in burn stands. Once again, it should be highlighted that most vegetation variables are linked. Therefore, it would be imprudent to incorporate, for example, low coarse DWM densities from the 1993 burn stands into a management regime knowing that there will be few inputs from the high snag densities that also occur in burn stands.

5. Conclusion

Differences occurred between burn and harvest stands in terms of vegetation and wildlife communities. However, considering this study compared fire disturbed stands to harvest stands that followed current timber harvest guidelines, the many similarities between disturbance types was encouraging. The potential for convergence exists. In some cases it occurred naturally, in others it will require manipulation at the time of harvest. For the latter case, the effects of manipulations at the harvest site following guidelines suggested by this study will require careful monitoring.

It is unlikely that we will be able to manage harvested forests such that they will be exactly like naturally disturbed stands, therefore we must ask ourselves at what level of sameness will we be satisfied. Is a harvested forest sufficiently managed if the human eye can detect no difference? Is the loss of one species acceptable considering the employment opportunities provided by timber harvesting? At what time after disturbance should we expect convergence to occur? Obviously, everyone will have different opinions on this subject and a consensus must be reached.

6. References

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